9

Experimental Electrical Testing

By STUDENTS

Compiled chiefly from data furnished by

SCIENCE TEACHERS AND STUDENTS IN UNIVERSITIES, COLLEGE PREPARATORY SCHOOLS, AND HIGH SCHOOLS

For the Science Teacher

WESTON ELECTRICAL INSTRUMENT CO.
NEWARK N. J.

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BROOKLYN, N. Y.

January 19th, 1914.

Weston Electrical Instrument Company,
Waverly Park,
Newark, N. J.

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Gentlemen:

The table of contents of your proposed Monograph B4 is before me and I am very much pleased that you are prepared to further cooperate with the Joint Committee on Physics, and to so substantially support a nation-wide movement for the improvement of Physics teaching. Reports have been received by the Committee conveying the consensus of opinion of hundreds of teachers and they show unanimous approval and appreciation of your Monograph B2.

While I cannot officially accept your Monograph B4 as a Committee publication until it has been submitted to the members of the Committee I wish to urge you to proceed with its publication. It admirably supports the conviction of the majority of our science teachers that we should use in the laboratory and on the lecture table chiefly such objects of instruction as are commonly met in the daily experiences of the people.

Your new charts and wiring diagrams will, I believe, be equally welcome. They are a great aid to classroom instruction and cuts made from them will greatly improve our textbooks.

Yours very truly,

J. A. Randall.

JAR/GJL

EXPERIMENTAL ELECTRICAL TESTING

A COMPILATION, INCLUDING PRACTICAL ELECTRICAL MEASUREMENTS ACTUALLY PERFORMED BY STUDENTS

MONOGRAPH B-4

April, 1914.

ISSUED FOR

SCIENCE TEACHERS IN EDUCATIONAL INSTITUTIONS

"Everybody needs to know something about the working of electrical machinery, optical instruments, ships, automobiles, and all those labor-saving devices, such as vacuum cleaners, fireless cookers, pressure cookers and electric irons, which are found in many American homes. We have, therefore, drawn as much of our illustrative material as possible from the common devices in modern life. We see no reason why this should detract in the least from the educational value of the study of physics, for one can learn to think straight just as well by thinking about an electrical generator, as by thinking about a Geissler tube."

From "Practical Physics." Black & Davis.

WESTON ELECTRICAL INSTRUMENT CO.
NEWARK, N. J.

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SUBJECTS.

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ARGUMENT

THE Weston Monographs were prepared with the definite object in view of attempting to co-operate with and assist science teachers in high schools and collegiate preparatory schools throughout this country.

Their context is exclusively on electrical subjects; and each deals with a particular theme.

For instance B–1 dwells upon the manifest advantages of training students engaged in laboratory work by means of standard apparatus, such as they will encounter in practical work after graduation. It also calls attention to the fact that it is inconsistent as well as unwise to attempt to perform modern progressive laboratory work by means of antiquated and obsolete apparatus. *It shows what should be done.*

B–2 contains a series of simple yet exceedingly instructive experiments, and presents suggestions that should be of great value in the preparation or amplification of an electrical course. *It tells what could be done.*

B–3 briefly describes several standard high grade and thoroughly reliable instruments, economical in price and particularly adaptable to high-school work.

In this Monograph B–4, we have compiled interesting and important data which will indicate some of the experiments which *are actually being performed* in progressive High Schools in these United States. We accomplished this by reproducing the actual work of students without revision or alteration, together with sketches, data-sheets, reports and instructors' comments, as well as apparatus actually used.

We desire to explain as briefly as possible how B–4 has been produced.

Early in the Fall of 1913, we issued a letter to over 7000 science teachers on our list, in which we directed attention to

the Monographs we had already issued, and requested suggestions relating to experiments in electrical measurements which they would like to see embodied in future Monographs. We were immediately deluged with replies, and as soon as it was feasible we began preparing data relating to the experiments most in demand.

We then conceived the idea of asking science teachers to furnish us with these experiments, instead of preparing them ourselves; and wrote to a number of those who were fortunate enough to possess a modern equipment, inviting them to contribute some specified exercises.

In this manner we hoped to fulfill the requests of science teachers by publishing the work of other science teachers.

The experiments offered are reproduced verbatim; but we have in some instances either simplified or elaborated connection diagrams. Otherwise the authority for the execution of the work is vested in the contributor cited. Necessarily there was much repetition, and it obviously became practicable to print only a few of the contributions we received; but we desire to gratefully acknowledge the assistance of those teachers whose work is not incorporated in this Monograph. Their tests were of great value to us, and in many cases it was exceedingly difficult to make a choice.

Entirely aside from their intrinsic pedagogical value, the majority of these experiments have a significance which cannot fail to arrest the attention of the progressive instructor. They prove conclusively that the trend of physics teaching is toward the practical application of fundamental principles.

They indicate also that laboratory work requiring the use of instruments of precision may be successfully performed by young students of either sex.

In conclusion we desire to direct special attention to the Nodon Valve and Rectifier experiments; because they are not only of the greatest interest pedagogically, but since they also possess utilitarian properties, in that they indicate how a teacher who has only alternating current service available, may easily and cheaply transform to direct current; and thereby open up a greater realm of electrical experiments specially suited to the High School Laboratory.

WESTON ELECTRICAL INSTRUMENT COMPANY.

GENERAL LABORATORY WORK

In preparing the minds of beginners in experimental electrical work, and in directing their attention to the ethical as well as the material considerations involved, it would be to their advantage to hear the following comments, which are adapted from an introduction to a loose leaf manual in Electrical Measurements. We are indebted to their author, Prof. James Theron Rood, Ph.D., of Lafayette College, for permission to use them.

I. PREPARATION FOR LABORATORY WORK

A well-trained experimenter, in any department of science, may at once be known by his ability to make clear, concise statements of the laws and phenomena of that department in which he is especially interested.

An electrical laboratory is a place designed to help men to acquire such characteristics, but it is of value to any man only in proportion as he approaches his work therein with the proper spirit, imbued with the desire to do and learn. The first requisite is to come to the laboratory knowing fully what you are to do, and how you are to do it. Read in advance the direction sheets for the given experiments, look up the references, be prepared to get the most out of *your* performance of the given experiment. If you do not come so prepared, you are almost sure to become confused as to what must be done and as to the order which must be followed. Required observations are likely to be omitted, time may be wasted on useless readings, interesting and valuable phenomena may escape your attention or be wrongly interpreted, and you may finish with a confused instead of a clear conception of the method and the value of the test. Make yourself master of the experiment, in the preparation for it, in the performance of it, and in the writing of the report

about it. The students who must continually run to an instructor for direction and advice can never rise very far.

II. PERFORMING THE EXPERIMENT

No general advice or directions can be given which will cover each and every experiment. Each test brings its own peculiarities, its own difficulties; but there are invariably certain things which mark the trained and careful experimenter. Some of these are given in what follows:

III. APPARATUS

All apparatus used in testing should be most carefully handled. What company would retain an employee who misused its instruments or machines?

Accidents may happen to even the most careful experimenters, but whenever they do occur, they should be reported *at once*. Placing the injured instrument back in its place without reporting its injury is the work of a *sneak*. Such action may result in the apparatus remaining unrepaired until a time when a co-worker, needing the apparatus for immediate use, discovers that it is injured and that it may have to be sent away for repairs. He is thus kept back in his work when, had the injury been known, suitable repairs might have been made before the apparatus was again needed.

IV. DIAGRAMS

Before beginning any experiment, make a clear diagram of the proper arrangement of all circuits to be used, with all connections, instruments, resistors, switches, cut-outs, etc., shown by the conventional symbols. **Use heavy lines for indicating conductors carrying large currents, such as electric power service wires, bus-bars, feeders for motors, etc., and light lines for potential circuits, such as leads to the e.m.f. terminals of wattmeters, voltmeters, etc.** Submit this diagram to the instructor for his criticism and approval. *Then connect up according to this diagram.* Make no changes in it without the approval of the teacher.

V. INSTRUMENTS

Almost without exception, all makes of ammeters have uninsulated, metal binding-posts, while voltmeters have posts encased in insulation. The two kinds of meters can thus be at once told apart. Millivoltmeters are frequently used as ammeters by connecting shunts in the line, the potential drop across these shunts being proportional to the current; the readings of the meter when its leads are placed across the terminals of the shunt will be proportional to the current flowing, and may be read directly in amperes. When so used the values of the scale divisions of the meter will depend upon the particular shunt used as well as upon the meter leads. Each millivoltmeter must always be used both with its own shunt and its own leads. The shunt is always connected in the line and the millivoltmeter across the shunt. Remember, ammeters go in the line, voltmeters go across the line. Never lay instruments on the floor or on a chair. Always put them on a table and then pass the wires through holes in the edge of the table or else so fasten them that there can be no chance of an instrument being pulled down onto the floor. If any instrument has a zero error reading, allow for it in your readings, or have it reset by means of its zero adjusting device. NEVER OPEN OR CLOSE A CIRCUIT AT ANY AMMETER BINDING POST. Trace out the polarity of any D.C. circuit before connecting in an instrument. Be sure that the current flows through the instrument in the right direction. If it does not, OPEN THE CIRCUIT BEFORE REVERSING ANY AMMETER LEADS. REVERSE VOLTMETER LEADS AT THE CIRCUIT END, NOT AT THE METER. Read all meters to one-tenth of the smallest division. Look for any parallax when making a reading.

VI. ORDERLINESS

During the performance of all tests, see that all instruments, switches, lines, etc., are kept in an orderly condition and not allowed to become a confused maze. After finishing an experiment, see that all instruments, rheostats, lamps and other pieces of apparatus are replaced in their proper places in their cases.

Coil up and put away all lengths of wire. Put everything

back in its place and leave the apparatus as well as all the tables, etc., free from all wires and in perfect order ready for the next users. When finished, replace covers on all motors or dynamos used. Next to success in the performance, orderliness in the handling of laboratory apparatus is the most important thing to be learned in a laboratory. Your care in this respect will be considered in determining your term grade.

VII. REPORTS

To be able to write a satisfactory report of an investigation is an art and accomplishment that should be the desire and pride of every engineer, in every walk of science. It is the keystone of all science. In its essence, an engineer's report is a why, a what, a how, a this and a therefore.

A good engineer must have knowledge, judgment and common sense. The laboratory, rightly used, is the best place for the development of such powers, and should be valued as such.

Let your laboratory motto be:

WORK—OBSERVE—THINK

EXPERIMENTAL ELECTRICAL TESTING

EXPERIMENT NO. 1

RESISTANCE MEASUREMENTS

The following experiments were selected from a number kindly contributed by Mr. William F. Evans, Instructor in Physics, Girls' High School, Brooklyn, N. Y.

They are copied from the laboratory note-book of the girl who did the work.

A modification of these methods is used in shop practice for a preliminary measurement of resistance wires in course of manufacture. To eliminate errors due to a variation in current, the wire and the rheostat are both connected with one pole of the cell, and a double-throw switch is used, so that the rheostat may be adjusted until the same deflection is obtained when current is passed through either circuit in rapid succession. Reference, "Laboratory Exercises," Fuller and Brownlee, page 270.

Resistance of a Conductor by the Substitution Method

Apparatus. Weston ammeter; dry cell; rheostat, 50 cm., No. 30 German silver wire; and leads.

(1) Connect up the cell, the ammeter and the unknown resistance in series, being sure that all contacts are *clean* and all connections tight. See Fig. 1.

(2) Substitute the resistance box (with all plugs removed) for the unknown resistance and then decrease the resistance of the circuit until the current is the same as before. See Fig. 2.

(3) What then is the resistance of the 50 cm. No. 30 G. S. wire?

STUDENT'S REPORT

(1) I connected up as in diagram the cell, the ammeter, and the unknown resistance (50 cm. No. 30 German silver wire),

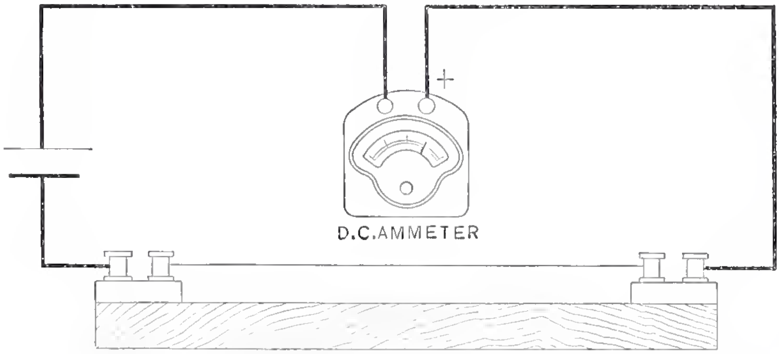

FIG. 1.—RESISTANCE MEASUREMENTS. (Reproduced from Student's Sketch.) Evans' Method.

Instrument Used is a Model 280, Weston Ammeter. Range 5 Amperes.

being sure that all contacts were clean and all connections tight. 6 amperes.

(2) I substituted the resistance box for the unknown resistance with all plugs out, and reduced the resistance of the cir-

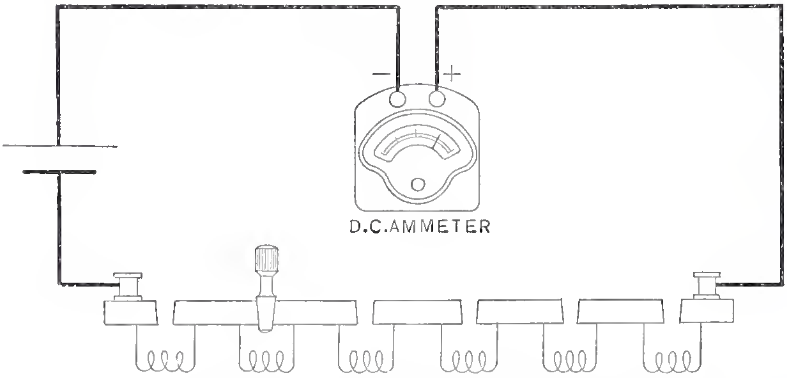

FIG. 2.—RESISTANCE MEASUREMENTS. (Reproduced from Student's Sketch.) Evans' Method.

Instrument Used is a Model 280, Weston Ammeter. Range 5 Amperes.

cuit by putting in plugs until the reading of the ammeter was the same as before—1.8 ohms.

(3) The resistance then of 50 cm. of No. 30 G. S. wire is 1.8 ohms, because the reading was the same when the resistance box was connected as when the German silver wire was connected.

EXPERIMENT NO. 2

COMPARATIVE RESISTANCES OF CONDUCTORS

Apparatus. As in preceding experiment; together with other wires of various sizes.

OBSERVATIONS

	Length of Conductor.	Area of Cross-section.	Amp.	Ohms.
(1) Varying Lengths	(1) 50 cm. G. S. wire (2) 100 cm. G. S. wire (3) 150 cm. G. S. wire	.05 sq.mm. .05 sq.mm. .05 sq.mm.	.60 .32 .20	1.8 3.4 .6
(2) Varying Areas . . .	(1) 50 cm. G. S. wire (2) 50 cm. G. S. wire (3) 50 cm. G. S. wire	.05 sq.mm. .10 sq.mm. .15 sq.mm.	.60 1.04 1.34	1.8 .8 .5
(3) Varying material.	(1) 50 cm. G. S. wire (2) 50 cm. brass wire (3) 50 cm. copper wire	.05 sq.mm. .05 sq.mm. .05 sq.mm.	.65 2.28 3.70	1.9 .3 .1

Description. I connected up the German silver wire as in preceding experiment. Then I substituted the resistance box as in preceding experiment. First I used 50 cm., then 100, last 150 cm. of German silver wire. Next I used wire with .05 sq. mm. cross section; then 10 sq.mm., finally, 15 sq.mm. After this I used 50 cm. of brass and 50 cm. of copper wire in place of the German silver wire.

March 21, 1913.

EXPERIMENT NO. 3

CONSTRUCTING AND TESTING A LAMP BANK RHEOSTAT

In commercial work, adjustable rheostats are extensively used; in fact they are indispensable when current from service lines is employed for experimental purposes.

For precision tests in laboratories, rheostats that are non-

inductive and which have a negligible temperature coefficient are preferable and often necessary, but in general commercial testing adjustable lamp bank rheostats are most in demand for current regulation, or for building up a load.

The rheostat described in this experiment should appeal to the science teacher because it is simple in construction and yet permits a wide range of adjustment owing to the ingenuity of its designer.

This rheostat was designed by Charles P. Rockwell, and constructed by him with the assistance of Gordon R. Milne, Barringer High School students, Newark, N. J. The tests made with it are their joint work.

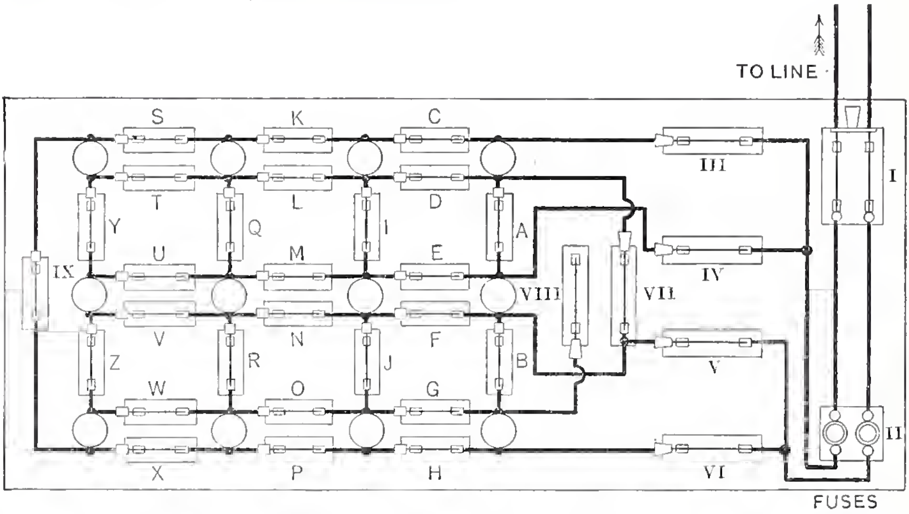

Fig. 3.—A Complex Lamp Bank.

Following is their own description:

This board was designed to allow any number of lamps, up to twelve, to be connected in multiple, series, or multiple series.

An oak board was obtained from the school shop. According to plan, a Perkins 25 amp. double-pole single-throw switch and a fuse block were placed at the extreme right, four Perkins single throw, single-pole switches were placed next to these, two for ingoing and two for returning current. Two other Perkins switches placed next allowed current to cross over to different banks of lamps. Twelve sockets were screwed at equal distances from each other.

The small cut-out switches were made by bending copper strips into jaws for receiving copper strips as blades. Holes were bored to receive jaws which were sealed in place with sealing wax.

Connections were made and lamps were screwed in as shown in Fig. 3.

Apparatus and Materials Required

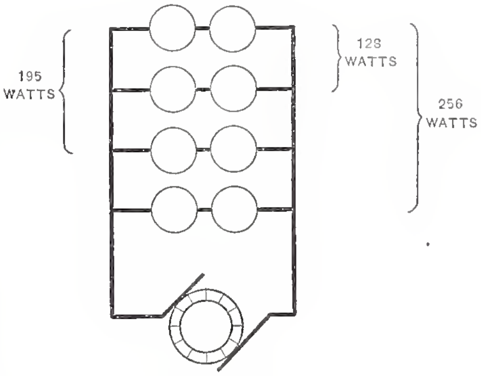

Fig. 4.

1 Weston voltmeter.
1 Weston ammeter.
1 portable testing set.
1 oak board 18×40 ins.
1 Perkins knife switch, 25 amp., double pole, single throw.
6 Perkins knife switches, 25 amp., single pole, single throw.
Sheet copper for making 27 switches (jaws and blades) which may be replaced with Trumbull single-pole, single-throw switches.
1 Edison double-plug cut-out.
12 Bryant porcelain receptacles, keyless.

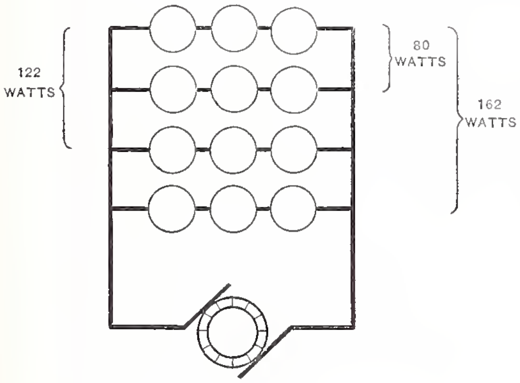

Fig. 5.

12 carbon filament 32 C.P. lamps.
2 fuses, mica cap, 15 amp.
15 ft. No. 14 (B. & S. gauge) bare copper wire.

Directions for Operating and Testing

Note. All switches not specified *closed* must be *open*. For all lamps in multiple: Close III, IV, V, VI, VII, VIII. *C*, *D*, *E*, *F*, *G*, *H*, *K*, *L*, *M*, *N*, *O*, *P*, *S*, *T*, *U*, *V*, *W*, *X*.

For all lamps in series. Close III, VI, IX. *A*, *F*, *I*, *K*, *Q*, *V*, *W*, *P*, *G*.

For Multiple Series Grouping

Three groups in series, each group containing four lamps in multiple. Close all except IV, V, VII, VIII, IX.

Two groups in series, each group containing four lamps in multiple. Close all except III, V, VII, VIII, IX.

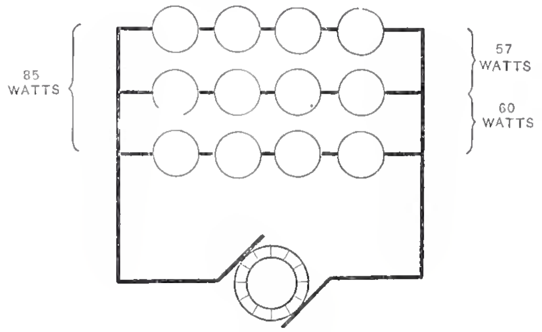

Fig. 6.

ARRANGEMENT

Multiple Watts.	No. of Lamps.	Series Watts.	Multiple Series. See Fig. 4		Watts.
			Groups of	No. in Mult.	
124	1	125	2 in series	2 in mult.	128
248	2	60	2 in series	3 in mult.	195
368	3	37.5	2 in series	4 in mult.	256
485	4	27			
585	5	20			
695	6	15	Multiple Series. See Fig. 5		
845	7	12.5	3 in series	2 in mult.	80
955	8	10	3 in series	3 in mult.	122
1080	9	8	3 in series	4 in mult.	162
1197	10	7			
1310	11	6			
1420	12	5	Multiple Series. See Fig. 6		
			4 in series	2 in mult.	57
			4 in series	2 in mult.	60
			4 in series	3 in mult.	85

WATTS PER LAMP IN ABOVE ORDER 1st COLUMN

Lamp No......	1	2	3	4	5	6	7	8	9	10	11	12
Watts	124	124	120	120	100	110	150	110	135	118	113	110

RESISTANCE PER LAMP

Lamp No.		1	2	3	4	5	6	7	8	9	10	11	12
Res......	Hot	112	112.2	116	116	139.2	126.3	124.2	126.3	118.8	118.0	123.2	126.3
Res......	Cold	225	230	240	230	235	235	230	245	225	242	235	240

R (hot) was when filaments were incandescent.

$$\text{Formula used } R=\frac{V^2}{W} \quad \text{or} \quad R=\frac{118^2}{W}.$$

R (cold) was when lamps were at room temperature (22° C.). Results were obtained by measurement with a portable testing set.

EXPERIMENT NO. 4

TEST OF FUSES

From Lafayette College, Department of Electrical Engineering, Laboratory Direction Sheets. Available through the courtesy of the author, Professor J. T. Rood.

References: Barr, Direct Cur. Elec. Eng., p. 479; Swenson and Frankenfield, Vol. I, p. 342; Standard Handbook for Elec. Engs., p. 585; Foster's Handbook, pp. 217, 1275.

Purpose. Every electric circuit should be provided with some form of apparatus designed to prevent the flow of any excessive current which might start a fire or burn out any apparatus. The insurance companies require that all lighting and motor circuits shall be so fused or protected that the current-carrying wire shall never be overheated. Such protective devices are called cut-outs. They may be pu tinto two classes, fuses and circuit breakers. Fuses, according to their arrangement, may be divided into three classes, open, expulsion and enclosed. Circuit breakers are somewhat more convenient, but are much more costly and occupy more space. They are better for circuits carrying large current, or where the circuit is liable to be opened or overloaded frequently, since they are more sure of opening the circuit.

Construction. Fuses are merely strips of metal of such shape and material as will fuse or " blow " before any excess current can flow for any length of time. The I. R. losses in the

metal due to the current passing causes the strip to become heated. If the heat is generated faster than it can be radiated, the fuse material melts and the circuit is thus opened, provided the arc does not hold between the terminals of the fuse block on account of the metallic vapor which may be left in the air between them. This limits the amount of current which a given fuse can safely break, unless there is provided some means of expelling the hot vapor (expulsion fuses), or of condensing it (enclosed fuses). In this last the vapor is supposed to be immediately condensed in the spaces between the granules of the non-inflammable, non-conducting material which fill the tubes. On account of the variation of the alloy in the different parts of the fuse wire, as well as on account of the effect of air currents, open fuses cannot be depended upon to always blow at the same current with the same length and diameter of fuse wire. For open fuses alloys of lead, antimony and bismuth are mostly used. Enclosed fuses are mostly of zinc. For large fuses copper is sometimes used, but it is liable to hold the arc through its vapor.

Object. The object of this experiment is to test some commercial fuse wire and to determine the relation (*a*) between length and the fusing current (*b*) between diameters for this last, all diameters of wires tested should be of the same make), (*c*) to investigate the construction and action of some types of enclosed fuses.

Apparatus. Various diameters of fuse wires, fuse block with adjustable terminals, adjustable resistor, Weston ammeter and inch scale, also line switch.

Part I. Set the terminals of the fuse block $1\frac{1}{2}$ inches apart in the clear and insert a length of fuse wire. Connect the fuse block in series with the ammeter, adjustable resistor and switch; and connect the whole across the D.C. supply circuit. See that the resistance is set to allow only a small current to flow, close the switch and slowly increase the current until the fuse blows. Repeat with the same size of wire for fuse lengths of 2, $2\frac{1}{2}$, 3, and $3\frac{1}{2}$ inches. Repeat this series for all the different diameters of wire given you. Record make of wire, rated capacity, and blowing current. Calculate and record the percentage ratio between the rated capacity and the blowing current. Note carefully the construction of each.

Report. Describe what you did. Plot curves showing (*a*) relation between length and fusing current for wires tested, (*b*) relation between diameter and fusing current for a given length of fuse. The form of curve for this last is usually:

$$d=(I/a)^{\frac{2}{3}},$$

where d = diameter of wire;
I = fusing current, and
a = constant depending on the composition of the wire.

Give good sketches of the construction of the enclosed fuses tested and give description of the details of each.

Questions. (*a*) Do you think the size or mass of the terminals of the fuse block can affect the value of the fusing current?

(*b*) If, so, how?

(*c*) Would this effect be proportional for all lengths of the fuse wire? Why?

(*d*) Why should the current in every case be increased slowly?

(*e*) Why should the enclosed fuses be given a preliminary heating before being blown?

EXPERIMENT NO. 5

THE FUSING EFFECT OF AN ELECTRIC CURRENT

The following experiment on fuses was supplied by Mr. Milton M. Flanders of the Bliss Electrical School, Takoma Park, Washington, D. C. It is so clean-cut and practical that comments are superfluous. Sketch is a reproduction of the one sent in by the students performing the test.

TEST NO. A–400

Heat

A study of the fusing effect of an electrical current.

Object of Test

To determine the current and time required to melt fuses under various conditions.

Apparatus Required

1 ammeter (0–100)	Various fuses
1 rheostat	1 circuit breaker
1 stop watch	1 switch
1 thermometer	Connecting wires

Conduct of Test

I. Preparation. Set up the apparatus as per diagram, connecting to a source of low potential and high current, as a storage battery. Close switch S and after inspection by instructor, admit current and correct polarity of ammeter if necessary. See Fig. 7.

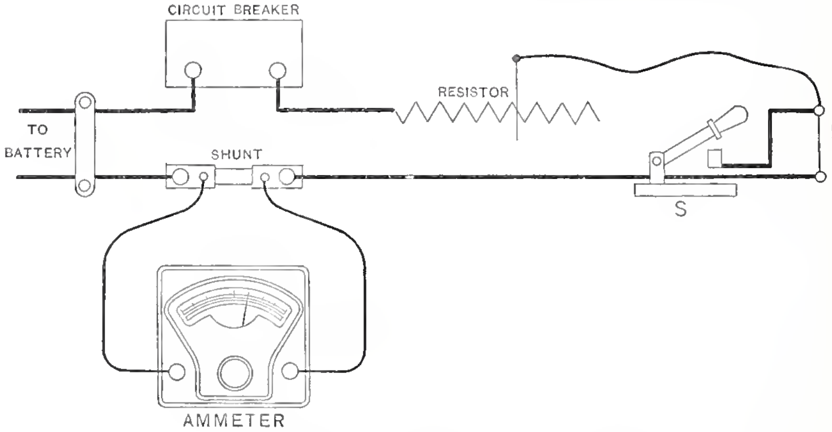

Fig. 7.—Study of the Fusing Effect of an Electrical Current. (Reproduced from Students' Sketch.) Flanders' Method.

Instrument Used was a Model 1, Weston Ammeter. Range 100 Amperes.

Note.—For all ordinary laboratory work, fuses that will "blow" at 1 to 20 amperes will suffice, and an ammeter of lower range than the above will be preferable.

II. Operation. (*a*) Admit current to 200 per cent rating of fuse under test, holding this constant by means of the rheostat R. Open switch S and simultaneously start stop-watch. Note the exact time required for the fuse to open the circuit. Repeat at least three times.

(*b*) Repeat above with different fuses, as directed.

(*c*) Repeat above on increasing current, the rate of increase being 1 ampere per minute, and tabulate results.

(*d*) Repeat operation (*a*) with the fuse wire in contact with some foreign insulating substance.

(*e*) Repeat operation (*a*), first raising temperature of fuse 50° C., by means of a heating chamber.

III. Calculation. Tabulate all results as indicated below:

Fuse.	Wire.	Length.	Deg. C.	Rating.	Amps.	Time.	Note.
Link	Shawmut	1.625	17.8	6	12	10 11 11 Avg.10.66+	

Report on Test No. A–400

Instrument used: Weston Model 1, Ammeter No. 5378. Centigrade Thermometer No. 3.

DATA

Operation (*a*)

Type.	Wire.	Length, Ins.	Temp. Deg. C.	Rating, Amps.	Amps.	Time, Sec.	Remarks.
Daum	Shawmut	1.625	22	6	12	8.6	Average
Daum	Shawmut	1.625	22	6	12	7.2	Time
Daum	Shawmut	1.625	22	6	12	10.0	8.93+ sec.

Operation (*b*)

Type.	Wire.	Length. Ins.	Temp. Deg. C.	Rating, Amps.	Amps.	Time, Sec.	Remarks.
Link	Shawmut	1.625	17.8	6	12	10	Average
Link	Shawmut	1.625	17.8	6	12	11	Time
Link	Shawmut	1.625	17.8	6	12	11	10.66+sec.

Operation (*c*)

Type.	Wire.	Length, Ins.	Temp. Deg. C.	Rating, Amps.	Amps.	Time. Sec.	Remarks.
Daum	Shawmut	1.625	21	6	12	12 min. 4 sec.	
Daum	Shawmut	1.625	21	6	10	9 min. 20 sec.	
Daum	Shawmut	1.625	21	6	10	9 min. 12 sec.	

OPERATION (*d*)

T pe.	Wire.	Length. Ins.	Temp. Deg. C.	Rating, Amps.	Amps.	Time, Sec.	Remarks.
Link	Shawmut	1.625	17.8	6	12	21	Average
Link	Shawmut	1.625	17.8	6	12	19	Time
Link	Shawmut	1.625	17.8	6	12	22	20.66+ sec.

NOTE.—In operation (*d*) the fuse wire was in contact with a marble block for .75 in. of its length.

OPERATION (*e*)

Type.	Wire.	Length. Ins.	Temp. Deg. C.	Rating, Amps.	Amps.	Time, Sec.	Remarks.
Link	Shawmut	1.625	49	6	12	8.2	Average
Link	Shawmut	1.625	49	6	12	7.2	Time
Link	Shawmut	1.625	49	6	12	8.0	7.8 sec.

NOTE.—None of the above fuses would blow at rated current and normal temperature of surrounding air.

Above test performed by F. G. Shipley and L. T. Petit.

Instrument repairs are expensive!

Fuses are cheap!

Why not insist that students insert a fuse between the load and the ammeter in all tests, so that the ammeter cannot be burned out or overlo ded?—Compiler's Note.

INDUCTION

We requested Mr. Geo. M. Turner of the Department of Physics and Chemistry, Masten Park High School, Buffalo, N. Y., to contribute some exercises on Induction, because the effects due to induction must often be taken into consideration in the designing or use of commercial apparatus in order to obtain efficient results. In this respect, the effect of induction may be beneficial or harmful, but a knowledge of this phenomenon is always necessary before a student can make any progress in acquiring even an elementary knowledge of electrical measurements.

Mr. Turner intends to include the following experiments in his physics course and writes concerning them as follows:

" Your request for an experiment on Induction for the forthcoming Monograph received.

"It is my understanding that you desire an experiment that will include the center-scale millivoltmeter. As my pupils have not as yet used this instrument for their induction work, it would be impossible to furnish any results from their standpoint.

" Recently, I used the instrument in a series of induction tests, such as our high-school young people make, and found that while not as sensitive as the ordinary D'Arsonval Galvanometer used in high-school work, it was sufficiently sensitive for such experiments as our young people would need to do. The prompt return of the pointer to the zero reading and the ease of watching the scale made the millivoltmeter seem much better adapted for this work than was the galvanometer.

" Later I tried the millivoltmeter in connection with the 'Student-sliding-contact Wheatstone Bridge' of the wire type. With resistances about 10 ohms, the instrument was all that could be desired, admitting of the exact location of the contact to within a millimeter. With resistances about a hundred ohms the instrument gave a width to the neutral point of between 2 and 3 millimeters. When the resistance was increased to 1000 to 4000 ohms, the neutral point was extended to approximately 10 millimeters. By increasing the battery power for the higher resistances from 1 cell to 3 cells, the range of the neutral point was reduced to 2 or 3 millimeters (for the 4000 ohms).

" These results indicate an amply sensitive instrument for such work in the hands of the high-school student, as his results need not vary as much as 1 per cent. It is very likely that many of the resistance boxes, used in the high-schools, will vary as much, or more than 1 per cent. Again, the prompt return of the pointer to zero reading proved of great assistance, and a marked time saver.

" In general, I am very much pleased with the results of the working of the instrument. It is my intention to order enough for our laboratory work early next year.

" Very sincerely,

" (Signed) Geo. M. Turner.

" It may be proper for me to advise you that the customary (high school) slide-wire bridge uses one meter of wire."

EXPERIMENT NO. 6

CURRENTS INDUCED BY MAGNETISM

Object of Experiment

(1) To observe the effect of moving a magnetic pole into a coil of wire.

(2) To compare the effect of moving a magnetic pole into the coil with that of removing the pole from the coil.

(3) To observe the effect of moving unlike poles into a coil.

(4) To observe the effect of moving the coil instead of moving the magnet.

(5) To observe whether the induced current aids or opposes the movement between the coil and the magnet.

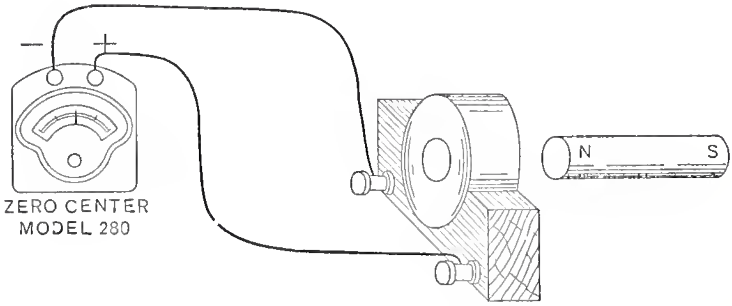

Fig. 8.—Current Induced by Magnetism. Turner's Method.

Instrument Required is Model 280, Weston Zero Center Millivoltmeter. Range 100-0-100 Millivolts.

Apparatus

Weston millivoltmeter, with zero in the center of the scale. Coil of wire (50 to 100 turns of No. 28 double-cotton covered wire).

Small bar magnet.

Connecting wires.

Procedure

I

Preliminary. Before making the tests called for in this experiment it is desirable to find out the direction of thrust of the milli-

voltmeter needle, when current enters it by the right-hand binding post. In order to determine this, a thin strip of zinc may be fastened to one end of a connecting wire and the other end attached to the left-hand binding post of the millivoltmeter. With the second wire attached to the right-hand binding post, the zinc and copper ends of the wires may be dipped in ordinary hydrant water, or (if this has not enough conductivity) into hydrant water with a few minute crystals of salt added.

The information gained by the thrust of the needle under these conditions serves as a guide to the direction of current flow through the millivoltmeter during the tests that follow. Of course, current entering the millivoltmeter by the left-hand binding post produces a thrust of the needle in a direction opposite to that caused by current entering by the right-hand binding post.

Connect the terminals of the coil to the millivoltmeter.

Manipulation

II

(*a*) While watching the millivoltmeter, the North pole of the bar magnet may be thrust into the center of the coil and held there. The movement of the needle, during the movement of the magnet, to left or right is noted. See Fig. 8.

(*b*) Upon removing the North pole, a movement of the needle in a direction opposite to that of the entering pole is observed.

(*c*) To show that a temporary current through the millivoltmeter is due to the relative motion between the coil and magnet, the coil may be moved toward and from the North pole of the magnet, with results similar to those observed under (*a*) and (*b*).

(*d*) When the South pole, instead of the North pole is used, a second series of observations is obtainable, which gives movements of the needle opposite to those of (*a*), (*b*) and (*c*).

(*e*) In order to show that the rate at which the lines of force (thrust out by the magnet) are cut by the wire of the coil, alters the deflection of the needle (and hence the electro-motive force of the current produced), the magnet may be made to enter the coil at first slowly, then more rapidly.

(*f*) After a record has been made of the result of the observations of (*a*), (*b*), (*c*), (*d*), it is quite possible, by use of the preliminary information, bearing upon the movement of the millivoltmeter needle when the current enters the right-hand binding post, to find out (by Ampere's hand rule) whether the polarity of the coil of wire is such as to produce a magnetic pole that helps or hinders the movement between the coil and magnet in each of the trials (*a*), (*b*), (*c*), (*d*).

EXPERIMENT NO. 7

CURRENTS INDUCED BY ELECTRO MAGNETISM

Object of Experiment

(1) To observe the effect in a coil of wire, of moving another coil of wire, through which a current is flowing, toward the former coil and away from this coil.

(2) To observe the change of effect when the moving coil has a soft iron core.

(3) To observe the effect in a coil of wire of " making " and " breaking " the current in an adjacent coil of wire.

(4) To observe the change of effect when the two coils have a common soft iron core.

(5) To observe whether the induced current aids or opposes the movement.

Apparatus

Weston millivoltmeter, with zero in the center of scale.
2 coils of wire 50 to 100 turns each of No. 28 D. C. C. wire.
2 dry cells.
Soft iron core.
Connecting wires.

Procedure

Connect up the apparatus as shown in the diagram, leaving the two coils apart. See Fig. 9.

(*a*) With current flowing through the coil *A*, it should be moved toward the coil *B* until the two touch and have their

axes coincident. The direction of movement of the needle during the movement of the coil is noted.

(*b*) After allowing the needle to come to rest, the two coils may be separated and the direction of movement of the needle during motion again noted.

(*c*) By placing a soft iron core within the coil *A* and repeating the movement to and from coil *B*, the change in the intensity of the thrust of the needle of the millivoltmeter and hence a change in the electro-motive force in the circuit, is observable.

(*d*) With coils *A* and *B* side by side (axes coincident), the current through coil *A* may be opened and closed by use of one of the wire ends at the battery. The direction, as well as

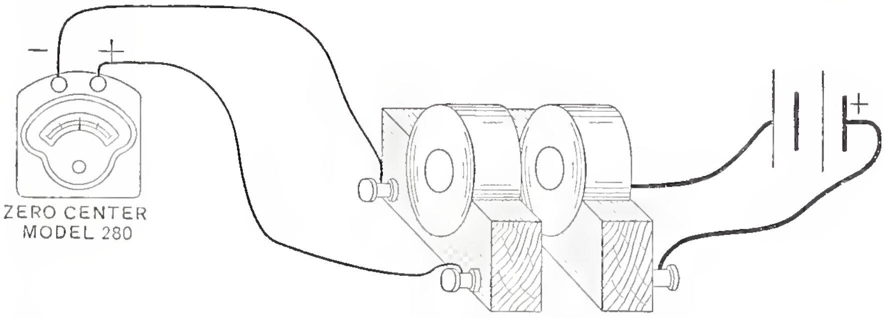

FIG. 9.—CURRENT INDUCED BY ELECTRO-MAGNETISM. Turner's Method.

Instrument Required is Model 280, Weston Zero Center Millivoltmeter. Range 100-0-100 Millivolts.

the intensity of the thrust of the needle should be noted, both on closing and on opening the circuit. The intensity may be still further varied by the introduction of the soft iron core into the coils.

(*e*) While recalling the direction of thrust of the needle when current was made to enter the right-hand binding post of the millivoltmeter from the simple cell of the previous experiment, it is possible to trace out, by Ampere's hand rule for finding the polarity of a solenoid, whether the magnetic poles, formed by introduction in *B*, assisted or hindered the movement of the magnetic poles in *A*; or whether, on making and breaking the circuit in (*d*) the polarity of *B* and *A* was such as to hinder making contact and prolong the contact when made, or the reverse.

We hoped to obtain additional exercises on induction from other sources, showing, for instance, the inductive effect of an electro-magnet in shunt with a lamp and an instrument; so that students would have a clear conception of the commercial importance of induction phenomena. See "Practical Physics," Black and Davis, page 312, and "Elements of Electricity," Timbie, Chapter 10.—COMPILER'S NOTE.

THE PHOTOMETER

In the realm of practical physics, the photometer plays a prominent part because it is the accepted apparatus for determining the candle-power or luminosity of electric lamps or other lighting devices as expressed in terms of a standard lamp or some other established value of light. Of course the traditional standard candle is obsolete, and the amylacetate standard lamp has also been relegated to oblivion; both giving place to the incandescent lamp of known illuminating power.

In view of the fact that the decrease in efficiency of an incandescent lamp is large when carrying an underload, and that the life of the filament is shortened enormously by an overload, stress should be laid upon the reason for marking a lamp so as to indicate its correct e.m.f.

It gives us pleasure to find that many high schools use the photometer in their physics course, and that we are therefore able to present the results of tests made by high-school students.

EXPERIMENT NO. 8

AN EXERCISE IN PHOTOMETRY

Mr. Lewis H. Fee, Head of the Science Department of the Everett High School, Everett, Washington, contributed the following excellent exercise, together with the comments, directions and conclusions relating thereto, which we produce verbatim:

"The following laboratory problem is one of a list of those required of all regular physics students in the Everett High School. The following set of data is about an average of the results as a whole. No originality is claimed for the problem and the only excuse for its publication is to offer one of the

problems which show the correlation between the laboratory work in light and electricity.

" *Directions.* Set up the apparatus as in the accompanying sketch. Have your set-up checked by the instructor before closing the switch. Move the screen along the scale until the two sides are equally illuminated. Read the distance from the unknown lamp; and since the scale is 100 cm. long, if you subtract this reading from 100 you will have the distance from the standard. Make three or four determinations of this distance and use the average in the equation:

$$\text{c.p. of standard} : \text{c.p. of unknown} :: L^2 : l^2,$$

where L = distance from screen to standard lamp and
l = distance from screen to unknown lamp.

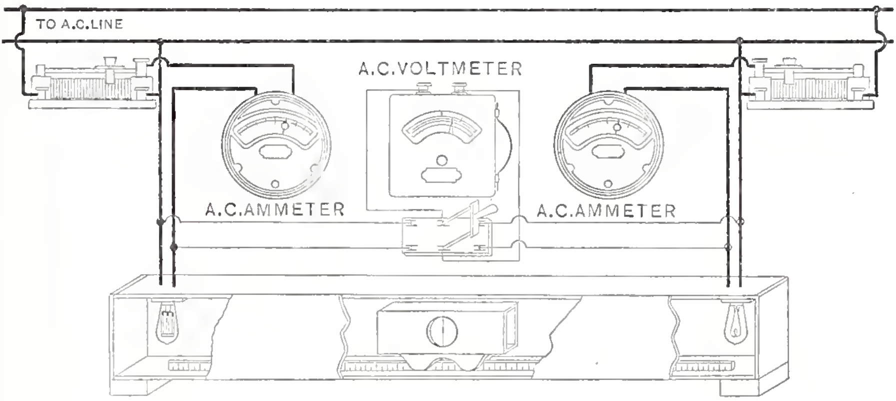

FIG. 10.—AN EXERCISE IN PHOTOMETRY. Fee's Method.
Instruments Used were two Model 156 Weston Ammeters, and a Model 155 Weston Voltmeter. This outfit may also be used with direct current.

" This equation is derived from the well-known law, 'The intensity of illumination varies inversely as the square of the distance.' Since the intensity is the same at the screen, the intensity or c.p. of the source must vary directly as the square of the distance.

" The candle-power is measured at different voltages to show that there is a relation between the voltage and the candle-power. Lamps of different kinds and ages were used to gain some idea of economy in electric lighting.

" *Apparatus.* A home-made photometer. (This photometer is merely a rectangular box 16×16×116 cm. with doors at either end for the insertion of the lamps and also one near the center for moving the screen. See Fig. 10.

"The screen is made of two cakes of paraffin separated by a piece of tinfoil and held before a window cut in a rectangular metal box 5×5×12 cm. The ends of this metal box are open towards the lamps that are placed in either end of the large box. It is 100 cm. from center to center of the lamp sockets.

"Two slide resistances.

"Two Weston A.C. ammeters, Model No. 156.

"One Weston A.C. voltmeter, Model No. 155.

"One standardized incandescent carbon lamp 31.03 c.p. at 105 volts.

RESULTS

CARBON

Volts	105	95	85
Amperes	0.76	0.72	0.65
Distance to screen	50.9 cm.	46.4 cm.	41.4 cm.
	50.5 cm.	46.4 cm.	41.6 cm.
	50.5 cm.	46.0 cm.	41.4 cm.
Approximate age in hours of use	New	New	New
Rating	100 watt	100 watt	100 watt
Watts per c.p.	32.69	23.01	15.58
Per cent decrease in voltage	....	9.5	19
Per cent loss in c.p.	....	29	52

CARBON

Volts	105	95	85
Amperes	0.90	0.80	0.70
Distance to screen	49.6 cm.	45.5 cm.	36.1 cm.
	49.5 cm.	44.9 cm.	36.0 cm.
	49.7 cm.	45.9 cm.	37.3 cm.
Approximate age in hours of use	1000	1000	1000
Rating	32 c.p.	32 c.p.	32 c.p.
Candle-power	30.05	21.51	10.55
Watts per c.p.	3.14	3.53	5.64
Per cent decrease in voltage	....	9.5	19.0
Per cent loss in c.p.	....	28	65

MAZDA

Volts	105	95	85
Amperes	0.35	0.35	0.35
Distance to screen	51.3 cm.	47.6 cm.	42.4 cm.
	51.0 cm.	47.2 cm.	42.3 cm.
	50.5 cm.	47.0 cm.	43.0 cm.
Approximate age in hours of use	New	New	New
Rating	40 watt	40 watt	40 watt
Candle-power	33.43	24.94	17.05
Watts per c.p.	1.10	1.37	1.74
Per cent of decrease in voltage	....	9.5	19
Per cent loss in c.p.	....	23	49

MAZDA

Volts	105	95	85
Amperes	0.40	0.40	0.40
Distance to screen	51.4 cm.	47.0 cm.	42.1 cm.
	51.0 cm.	46.7 cm.	41.0 cm.
	51.4 cm.	46.5 cm.	41.5 cm.
Approximate age in hours of use	500	500	500
Rating	40 watt	40 watt	40 watt
Candle-power	34.35	23.88	15.65
Watts per c.p.	1.22	1.59	2.17
Per cent decrease in voltage	....	9.5	19
Per cent loss in c.p.	....	30	54

CONCLUSIONS

"In order to arrive at any definite conclusions it would be necessary to test a large number of lamps, hence the conclusions arrived at here are only approximate.

"Incandescent lamps should be operated at nearly their rated voltage as the c.p. decreased approximately three times as fast as the voltage. It is also more economical, as is shown by the 'watts per c.p.'

"That the metal filament is the more economical since the 'watts per c.p.' are only about one-half what they are for the carbon filament.

"That in the old carbon lamp there was not only a decrease in c.p., but also an increase in current consumption, making it expensive to use.

"That the metal filament lamps are less affected by age and change of voltage than are carbon filament lamps.

"(Signed) WALTER SUNDSTROM,
"GRANT DURKEE."

Quiz for Students. Include a switch in the main line so that current will flow through a metal filament and a carbon filament lamp simultaneously when the circuit is closed. Note that the light from one lamp "arrives" at the screen more quickly than from the other; and that the light from one source also disappears sooner when circuit is broken. Why?

Does the light from one lamp travel more quickly than the other?—COMPILER'S NOTE.

EXPERIMENT NO. 9

PRACTICAL INCANDESCENT LAMP TESTING

(Prepared by the Compiler.)

The following experiments have a direct bearing on some of the problems encountered in the practical construction and testing of incandescent lamps.

They also serve to illustrate that a thorough mastery of the characteristics of Weston instruments is no insignificant accomplishment.

Mount a lamp socket with leads on a board having dimensions of about 3×6 inches.

Screw in a 32- or else a 16-c.p. *common carbon filament* 110-volt incandescent lamp.*

(1) Connect leads with a Wheatstone bridge or any portable test set, and measure the resistance of the lamp at room temperature. Record resistance and temperature.

(2) Substitute a 60- or a 40-watt *metallic filament* lamp and repeat the test. Record results.

Connect the leads with a d.c. service line.†

Include in the circuit the carbon lamp, the 1.5 ampere range of a Weston Model 280 ammeter, and a snap or knife switch. Also connect a voltmeter of suitable range across the terminals of the socket.

(3) Close the switch and let the current flow for about five minutes. Then break and instantly remake the circuit, keeping your eye on the pointer. Note that it will overswing slightly, before becoming steady. *Why?*

Notice the "dead beat" action of the pointer, and the rapidity with which it will assume its true position. Record in scale divisions the extent of the overswing. Record also voltage, and current consumed when pointer is steady.

---

* The "Gem" or G. E. Metallized Filament lamp will not serve for this experiment.

† NOTE.—Direct current is necessary for these tests; but if only A.C. service is available, a rectifier may be used to good advantage.

(4) Open the circuit and allow the lamp to cool for *at least* 5 minutes; then close the switch, watch the pointer, and study its action. Observe that there is now no visible overswing, but on the contrary a noticeable *lag* in its movement before it arrives at its position of maximum deflection. *Why?* Repeat test (3) and note that you get the same overswing as before.

Then open the switch, wait 5 minutes and repeat test (4). Record results.

(5) Substitute a 60- or a 40-watt *metallic filament* lamp and repeat tests (3) and (4). Record all results obtained. Describe the action of the pointer.

(6) Open the switch and insert the lamp almost up to its socket in a glass vessel containing water and cracked ice or snow. (A ½-gallon battery jar will do nicely.) Unless the leads and socket are waterproof, see that they remain dry. If water accidentally gets into the socket, unscrew the lamp and carefully dry all parts. Measure the resistance of the filament by means of a Wheatstone bridge or any other test set. Record results, giving resistance, and temperature of solution. The latter should be near 0° C. Repeat (6), substituting the carbon filament lamp. Let this cool for at least 40 minutes before recording resistance and temperature.

(7) State what strike you as the most significant characteristic differences between these filaments as revealed by the bridge measurements, (1), (2) and (6).

(8) Apply Ohm's law. Determine the respective currents which will flow through the filaments at room temperature, and at the temperature of melting ice, *according to this law,* when e equals voltage at the socket as previously recorded in tests (3) and (5), and r equals values obtained by bridge measurements. Compare the calculated current obtained at room temperature with the ammeter indications in the preceding tests (3) and (5); when current was steady; and if there are any differences state why.

(9) In any test, did any swing of the ammeter pointer indicate a current which was equal to or greater than the current which should flow, as obtained by calculation according to Ohm's law?

(10) Use any portable current indicator obtainable, in place of a Weston ammeter, and repeat tests (3) and (4) with it if

possible. If the range of the instrument is too high to get results with one lamp, use several in parallel. Record results.

(11) Explain the characteristics of the Model 280 ammeter that make it the most satisfactory portable instrument for these tests. Base your statements solely upon the results you have obtained. Do not generalize, or attempt to describe the instrument in detail.

(12) Answer the quiz question under photometer experiment, and explain its corelation to test (4).

ELECTROPLATING

Department of Physics, State Normal School,
Bellingham, Washington.
Dec. 12, 1913.

WESTON ELECT. INST. CO.,
Newark, New Jersey.

GENTLEMEN.—In accordance with the request in your last communication, I am mailing you a student's laboratory report on the electro-deposition of copper. Although the student under stood the experiment thoroughly his discussion is somewhat meager. I have indicated my chief criticisms.*

I do not believe in stereotyped forms of reports. I like to leave as much as possible to the judgment of the student, calling for additional discussion either orally or in writing, if not enough is given.

In this experiment I usually find the current obtained from the A.C. mains and Nodon valve constant enough to justify taking a number of amperage readings and striking an average.

In the second test of this report the current varied over so great a range † (from .85 amp. to 1.1 amp.) that it was necessary to note the length of time that it stood at each value and to compute the total number of ampere-seconds from the several amperages and the corresponding times.

Very respectfully,
(Signed) H. C. PHILIPPI.

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* Mr. Philippi states: "This boy has had only one year's work in Physics, taken when a sophomore in Normal School. Age 18 years."

† Variation in current strength was probably due to rise in temperature of the rectifier, or to partly exhausted solution.

EXPERIMENT NO. 10*

ELECTROPLATING WITH COPPER

" In electroplating with copper, how long will it take one ampere of current to deposit one gram of copper? What is the electro-equivalent of copper?

" The alternating current of the city lighting system is changed to a direct current by means of the electrolytic alternating current rectifier. See Fig. 11.

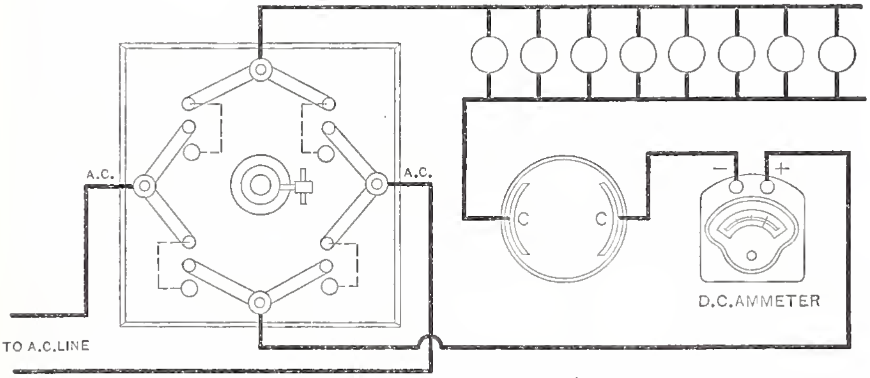

FIG. 11.—ELECTROPLATING WITH COPPER. Philippi's Method. Apparatus Includes an Electrolitic Rectifier and a Model 280 Weston Ammeter.

" The strength of the current is regulated by being run through the bank of incandescents.

" Difficulty was experienced in taking the second set of readings because of the inconstancy of the current, which fluctuated between 0.85 amp. and 1.1 amp.

RESULTS

	Trial (1)	Trial (2).
Wt. of copper deposited..............	.453 gm.	.568 gm.
Time of deposit......................	20 min.	30 min.
No. of amperes.......................	1.15	
Time 1 amp. will deposit 1 gm........	50.77	51.36
Electro equivalent...................	.0003283 gm.	.0003245 gm.

* This experiment is of special importance because a Nodon valve was used in connection with it. See page 000.—COMPILER'S NOTE.

"No satisfactory average could be found for the amperage in the second trial owing to the variation in the current.

"The amount of any metal which a current of one ampere will deposit in one second is called the electro-equivalent of the metal. For one metal this amount is always the same. Consequently this is a very accurate way to measure electricity. (Current strength.)

"(signed) L. O. GREENE."

March 6, 1913.

Instructors' appended comments:

"The method of dealing with the varying current should have been explained.

"In which direction does the metal in a plating solution always travel? Upon which electrode is it deposited?"

Copper plating is of great commercial importance because iron and steel are always plated with copper before giving them a finishing coat of nickel.—COMPILER'S NOTE.

EXPERIMENT NO. 11

THE ELECTRO-CHEMICAL EQUIVALENT OF A METAL

Substantially the same experiment as the foregoing is given herewith. It was contributed by Mr. Arthur H. Killen, Instructor in Physics, Flushing High School, Flushing, New York.

This experiment was performed and the report written by one of the senior students.* It was accompanied by a very creditable sketch which we reproduce. (See Fig. 12.)

Experiment. To find the electro-chemical equivalent of a metal.

Object. To find the electro-chemical equivalent of copper.

Apparatus. Two strips of copper, a copper sulphate solution plating bath, a Daniell cell, a Weston ammeter, wire, wire connectors.

* Mr. Killen informs us that the student's age was 18 years.

Work Done. I carefully weighed a strip of copper which was to be plated. I connected, in series, the Daniell cell, the Weston ammeter and the two strips of copper (the one carefully weighed) and another which had been placed in the copper sulphate solution electroplating bath. At intervals of one minute, I took readings of the Weston ammeter during forty minutes and averaged them to find the amperage or current strength during the forty minutes. I then removed the strip on which

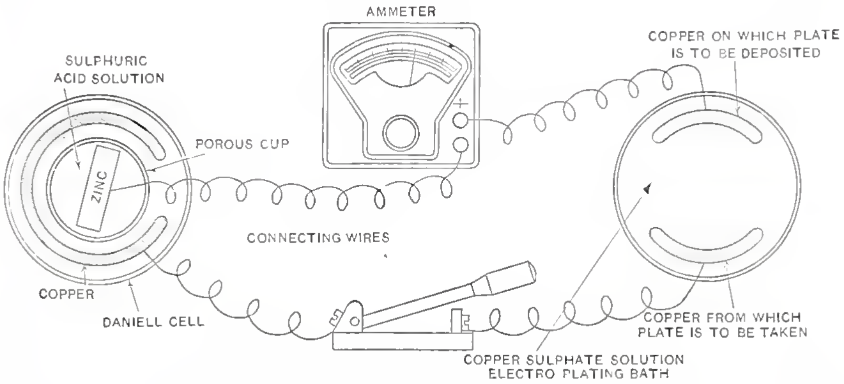

FIG. 12.—THE ELECTROCHEMICAL EQUIVALENT OF A METAL TEST. (Reproduced from Student's Sketch.) Killen's Method.

Instrument Used was a Model 1, Weston Standard Ammeter. Range 2 Amperes.

the copper was deposited from the electroplating bath and carefully rinsed and dried it. I then reweighed it.

OBSERVATIONS:

Weight of strip to be plated..................	22.952 grams
Weight of strip to be plated after forty minutes.	23.532 grams
Amount deposited in forty minutes...........	.58 gram
Average amperage or current strength........	.73 ampere
Amount deposited by .73 ampere in one hour.	.87 gram
Amount deposited by 1 ampere in one hour....	1.191 grams
Amount deposited by 1 ampere in one second..	.0003308 gram

Conclusions. The electro-chemical equivalent of copper is .0003308 gram, that is .0003308 gram of copper is deposited by one ampere in one second.

Mathematical Work

1st weight of object to be plated...... 22.952 grams by .73 amp.
Weight of object to be plated after forty minutes.................. 23.532 grams by .73 amp.
Weight of deposit at end of 40 minutes.. .58 gram by .73 amp.

$$\frac{.58}{40}=.0145, \text{ wt. deposited in one minute by .73 ampere.}$$

$$.0145\times 60=.87, \text{ wt. deposited in one hour by .73 ampere.}$$

$$\frac{.87}{.73}=1.191+\text{wt. deposited by one ampere in one hour.}$$

$$\frac{1.191}{3600}=.00033083, \text{ wt. deposited by one ampere in one second.}$$

Sylvanus Thompson gives .0003281 as the electro-chemical-equivalent of copper.

(Signed) Henry Greenberg,
(A. H. K., Instructor.)

THE USE OF THE ELECTRIC HEATER IN EFFICIENCY TESTS.*

By Ernest Reveley Smith, Syracuse North High School.

We are living in an age of commercialism. The relation of output to input is the great factor which determines our investments whether large or small. What is so general about us cannot fail to enter our laboratories. The toys that have been used so long as equipment are rapidly disappearing, their purposes well served. In their places are coming the newer commercial appliances, the experimental uses of which commend themselves instantly to the boy or girl as something worth while.

Among the commercial offerings to the Physics laboratory, few have greater possibilities than the various types of electric heaters. The very fact that the electric stoves, flatirons, immersion heaters, etc., are taking their places among the things of our every day life makes the use of them in the laboratory both interesting and profitable.

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* Reprinted from School Science and Mathematics, Vol. 13, 1913. Available through the courtesy of the author.—Compiler's Note.

Also they are the most adaptable of any of the laboratory equipment for work along efficiency lines, since all that is necessary for performing the experiment, besides the heater itself and the sources of current, is common equipment found in every laboratory. Generally we use an electric stove, with a voltmeter and an ammeter of suitable ranges, a flat bottom aluminum sauce pan, a watch and a thermometer.

The ammeter is connected in series with the stove and the voltmeter shunted across its terminals, see Fig. 13. (A wattmeter may be used in place of these instruments.) While the kettle, and the kettle with the water are being weighed, the current is turned on through the stove, so that it may come up to

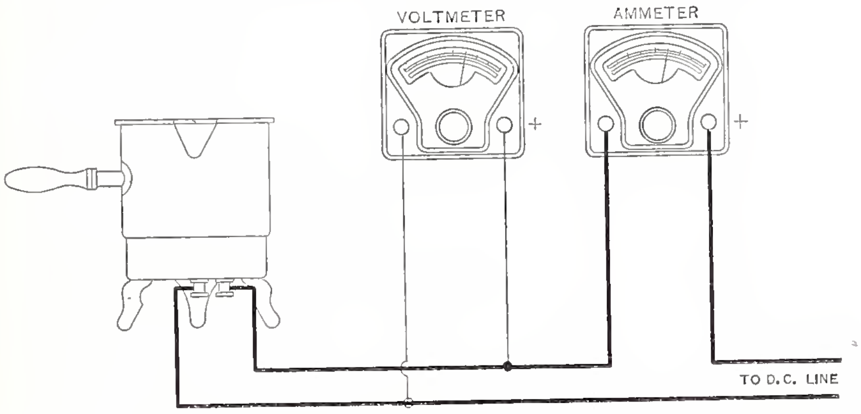

Fig. 13.—Instruments Shown are Weston Model No. 1, Voltmeter and Ammeter. Alternating Current Apparatus may be Substituted.

the normal working temperature. In this way very little heat is absorbed by the stove itself during the actual tests.

The temperature of the known weight of water is now taken and the kettle placed on the stove just as the stop watch is started. Voltmeter and ammeter readings are taken every minute and their average readings used, since there is usually considerable variation in the potential of city currents. At the end of a given time (ten minutes), the temperature of the water is read after stirring, and the current is cut off.

From the average current and fall of potential through the stove, its resistance is computed. The heat developed in the stove is computed from the well-known formula, calories $= 0.24C^2Rt$. The water equivalent of the kettle is found from

its mass and specific heat. Then the heat absorbed is the mass of the water including the water equivalent of the kettle, multiplied by the change in temperature. The efficiency is now obtained by dividing the calories absorbed by the calories developed.

The efficiency tests that have been made in our school for the past three years have given results varying from 45 to 50 per cent with one stove and from 65 to 70 per cent with another.

This experiment may be varied in several details. The apparent efficiency will be raised from 10 per cent to 15 per cent by using a large amount of water in place of 400 or 500 grams. Covering the kettle will usually raise the results by 3 per cent or 4 per cent. Again enclosing the kettle and stove in an asbestos jacket will give a result some 5 per cent to 10 per cent higher. This jacket is easily made from asbestos sheeting. Another variation brings into use the heat of vaporization. The experiment is continued until part of the water has boiled away. The kettle and contents are then weighed. The heat absorbed is equal to the sum of the heat necessary to bring all the water to the boiling point and that required to vaporize the water lost by boiling. This method will give results slightly higher than the first.

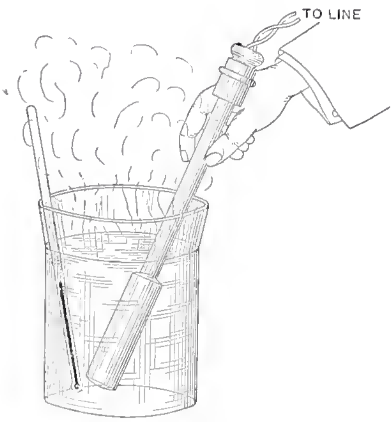

FIG. 14.—THE IMMERSION HEATER.

The immersion heater (see Fig. 14) gives much higher results than the stove. Our tests have shown an efficiency varying from 90 per cent to 98 per cent. The heater is tested in the same way as the stove. For general use about a laboratory this device is very satisfactory as it will heat water more quickly than gas and may be used with any kind of a dish.

The flatiron makes an excellent stove. In fact, many manufacturers furnish a stand to hold it inverted as well as a dish shaped to fit its working surface. Its efficiency is not as high as the immersion heater or stove, ranging from 40 per cent to 60 per cent, depending largely upon the shape of the kettle.

In laboratories having electricity but no stove, an incandescent bulb may be used for efficiency tests. If the experiment is performed first with a covered opaque calorimeter, and then with a glass jar, the relative amounts of energy given off as heat and light may also be determined.

In any of the above experiments the cost of electricity may be easily computed. If the pupil has found, earlier in his work, the cost of using a gas stove or burner for a similar length of time, he now has data for an interesting comparison.

Usually I divide the class into several squads of five or six for these experiments. While one squad is performing this experiment, the other members of the class are working on an experiment for which we have individual apparatus. One pupil from each squad weighs the kettle and water, another reads the thermometer, another has charge of the wiring, while others read the voltmeter and ammeter or hold the watch. This insures the constant attention of each member of the squad since he has something to do which is definite and vitally important to the experiment. Of course, the entire experiment may be performed by two pupils, if desirable, or made a class exercise, letting several pupils make the readings for the class. Whichever way it is done, it furnishes one of the most instructive as well as popular experiments in our laboratory.

EXPERIMENT No. 12

THE ELECTRIC DISK STOVE OR HOT PLATE *

Contributed by Mr. H. C. Philippi, Head of Science Department, State Normal School, Bellingham, Washington.

Object. To determine the efficiency of an electric disk stove or hot plate.

Apparatus. Electric disk stove; Weston voltmeter; Weston ammeter; two-quart copper tea-kettle; thermometer; balance and weights; watch. See Fig. 15.

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* Contributor states: "The results are those actually obtained by members of my class."—Compiler's Note.

For convenience in making connections the plug and flexible cord are removed from the stove, the stove mounted upon a board and its terminals permanently attached to binding posts in the board. The connections are, of course, those of any electrical power test. Before making the test which is to

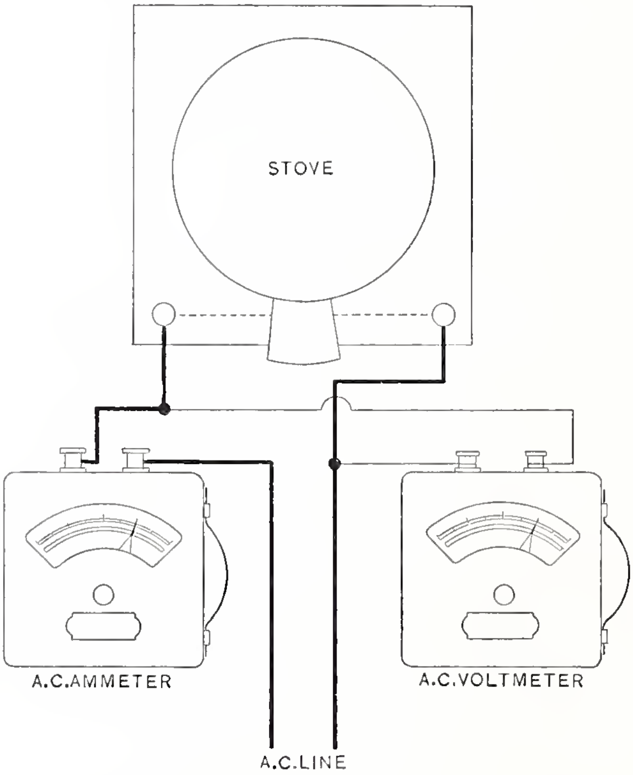

FIG. 15.—EFFICIENCY TEST OF AN ELECTRIC DISK STOVE OR HOT PLATE. (Reproduced from Students' Sketch.) Philippi's Method.

Instruments used were Model 155 Weston A. C. Ammeter, range 10 amperes, and Model 155 Weston A. C. Voltmeter, range 150 volts.

These instruments may also be used with direct current.

become a matter of record, it is well to make a preliminary test to get the stove into a steady thermal state. With the two-quart kettle, it will be found convenient to use about four pounds of water and allow current from 110-volt lighting mains to pass for about ten minutes. If the current runs much above five or six amperes, the time must be shortened.

Fig. 16.—Test of an Electric Flat Iron at the Barringer High School.

RESULTS OBTAINED BY STUDENTS

	Trial (1).	Trial (2).	Trial (3).
Weight of water used........	4.4 lb.	4.4 lb.	4.4 lb.
Weight of tea-kettle.........	1.0 lb.	1.0 lb.	1.0 lb.
Water equivalent of tea-kettle appr.....................	0.1 lb.	0.1 lb.	0.1 lb.
Initial temperature Fahrenheit	66.2°	59.0°	59.9°
Final temperature...........	129.2°	123.8°	123.8°
Rise in temperature..........	63.0°	63.8°	62.9°
Average voltage applied......	107.0	107.0	107.0
Average current in amp......	4.95	4.95	4.95
Time current ran............	10 min.	10 min.	10 min.
Heat gained (B.T.U.)........	283.5	287.1	283.0
Power input (watts).........	530	530	530
Energy input (watt-sec.) (Joules)..................	318,000	318,000	318,000
Heat equivalent of this energy 1055 watt-sec. = 1 B.T.U....	301.4 B.T.U.		
Efficiency of stove and kettle.	94.0%	95.2%	93.9%
Average efficiency...........	94.4%		
Cost per hr. to operate this stove at 10c. per kw. hr.....	5.3c.		

EXPERIMENT No. 13

COST OF OPERATING AND EFFICIENCY OF AN ELECTRIC FLAT IRON

Contributed by Mr. F. H. Beals, Barringer High School, Newark, N. J.

Object. To determine (1) Cost of ironing roller towels. (2) Efficiency of an electric flatiron.

Apparatus. Electric flatiron weighing 5.8 pounds rated as weighing 6 pounds and using 110 volts and 4.2 amperes, ironing board $38'' \times 14\frac{1}{2}''$, having no padding but covered with a roller towel stretched over the surface, dampened towels, Weston wattmeter (150 volts and 5 amperes), fuse blocks and connections, balance, scales and weights. See Figs. 16 and 17.

Performed by Elizabeth Arcularius. Assisted by Ruth A. Husk and Katharine Van Alen.

Manipulation

Directions. Sprinkle towels in preparation for ironing. Connect up iron and wattmeter as shown in diagram, Fig. 17. Let the current run $2\frac{1}{2}$ minutes to heat the iron. Iron rapidly so

as to waste as little heat as possible. To find the number of calories required to evaporate water, allow 80 calories per gram to heat from room temperature to temperature of evaporation, and 536 calories to evaporate water. Let A represent output in calories = loss of weight $\times(536+80)$. To find heating power of current, let B represent input in calories = watts $\times$ sec. $\times .24$. To find efficiency use $A \div B$. To find cost allow 10 cents per K.W. hr. Cost = watts $\div 1000 \times$ hr. $\times$ 10c.

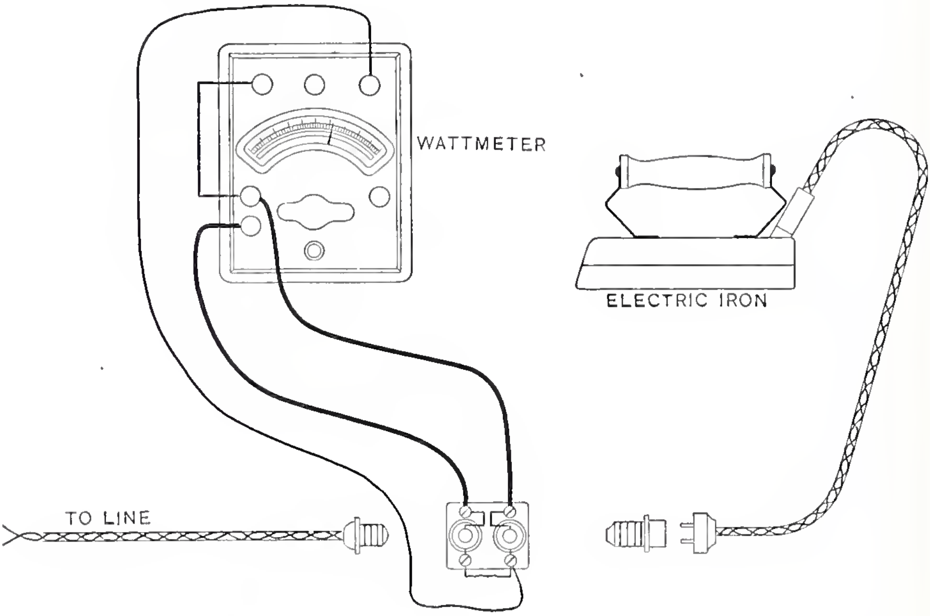

Fig. 17.—Beals' Wattmeter Method. (Reproduced from Connection Chart.)

Instrument used was a Model 16 Weston Wattmeter No. 2-A. Ranges 5 Amperes and 75 and 150 volts.

Method. General Principle: After the towels were dampened and weighed, the ironing was commenced. The wattmeter was read at regular intervals and recorded. When the towels were ironed they were weighed again. The length of time taken for ironing was also noted. The average number of watts was found, and the loss of weight in grams due to evaporation was determined. Throughout the experiments readings were taken as recorded below.

Case I. A wet towel was used. In finding the efficiency no allowance was made for evaporation or absorption.

CASE II. Conditions the same as in Case I.

CASE III. Five towels were dampened the evening before as for ordinary ironing. In finding the efficiency no allowance was made for evaporation or absorption.

CASE IV. A very damp towel was used. In finding the efficiency allowances were made: (1) For evaporation, due to the heat of the room, that would have taken place in the $8\frac{1}{2}$ minutes without ironing. (2) For absorption of moisture by towel covering board. (3) For evaporation (while airing 4 minutes) due to heat of towel, above room temperature.

No allowance was made for heating the iron. The temperature of the room was 22° C. It may be of interest to know that the relative humidity for the day was 55 per cent, but this was not used.

DATA AND CALCULATIONS

No allowances for correction

Case.	I	II	III
Condition of towel	1 wet	1 very wet	5 slightly wet
Weight wet	413.0 g.	421.2 g.	1255.4 g.
Weight ironed	273.5 g.	268.3 g.	1180.6 g.
Loss of weight	139.5 g.	152.9 g.	74.8 g.
Watts average	531.5	541.3	535.0
Time taken for ironing	13.5 min.	15.0 min.	8.5 min.
Efficiency	80.1%	80.6%	70%
Cost of ironing towels	$.012	$.013	$0.007

Allowance for corrections

Case.	IV
Condition of towel	1 very damp
Time to heat iron	1.5 min.
Watts—average	531.0
Weight wet	382.9 g.
Weight ironed	234.4 g.
Loss of weight by ironing	148.5 g.
Time actually consumed in ironing	10.0 min.
Weight of towel covering board (before ironing)	233.9 g.
Weight of towel covering board (after ironing)	247.6 g.
Increase in weight of towel covering board	13.7 g.
Weight of towel immediately after ironing	234.4 g.
Weight of towel dampened to same degree as one ironed	382.9 g.
Weight of same towel hanging $8\frac{1}{2}$ min. in air	366.6 g.
Loss of weight in this second towel	15.3 g.
Efficiency	88.5%
Cost of ironing one very damp towel	$0.007

Efficiency. Case I.

$$\frac{139.5\times(536+80)}{531\times13.5\times60\times.24}=\frac{85932}{103226.4}=83.2\%.$$

Case II.

$$\frac{152.9\times(536+80)}{541.3\times15\times60\times.24}=\frac{94186.4}{116920.8}=80.6\%.$$

Case III.

$$\frac{74.8\times(536+80)}{535\times8.5\times60\times.24}=\frac{46076.8}{65484}=70.4\%.$$

Case IV.

$$\frac{(148.5-13.7-15.3)(536+78)}{531\times10\times60\times.24}=\frac{73373}{76464}=96.0\%.$$

Conclusion. It seems to me that the reason why the efficiency is lower in Case III is because the amount of moisture to be evaporated is not so great in this case as in the others. Certainly the cost of ironing depends upon the quantity of water used in sprinkling.

The cost of ironing five towels moistened as in ordinary ironing was found to be 0.7 cent.

Computations were checked by George Y. Sosnow.

EXPERIMENT NO. 14

BOILING AN EGG BY MEANS OF ELECTRICITY

Contributed by Mr. Ernest R. Smith, Vice-Principal of the Syracuse North High School, Syracuse, N. Y.

Object. To find the cost of boiling an egg by means of electricity, and incidentally to determine the efficiency of the stove.

Apparatus. Small disc stove, Model 155 Weston Voltmeter; Model 155 Weston ammeter; aluminum kettle; thermometer;

platform balance and weights; eggs; watch and source of A.C. current.

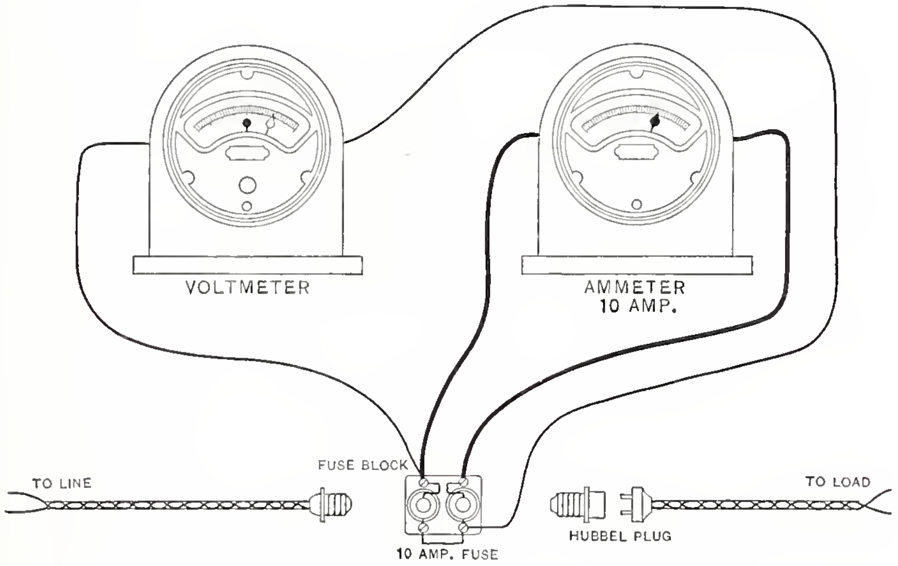

FIG. 18.—BEALS' A. C. VOLTMETER AND AMMETER METHOD. (Reproduced from Connection Chart.)

Instruments used were Model 156 Weston A. C. Voltmeter, range 150 Volts and Model 156 Weston Ammeter, range 10 amperes.

Results.

Weight of kettle	215.4 grams
Weight of kettle and cold water	1222.6 grams
Temperature of cold water	23.8° C.
Weight of kettle and contents after boiling egg for (3) min.	1151 grams
Temperature of boiling water for day	99.45° C.
Temperature change of water	75.65° C.
Fall of potential through stove	112 volts
Current through stove	5.31 amps.
Resistance of stove $\left(R=\frac{E}{C}\right)$	21.09 ohms
Heat developed in stove in 20 minutes $=.24\ C^2Rt=.24\times(5.31)^2\times21.09\times20\times60$	171,336 cal.
Water equivalent of kettle $(M\times S)$	47.4 grams

Heat absorbed by water in coming to the boiling point, 1054.6×75.65	79,780.5 cal.
Heat used in boiling away 71.6 grams of water 71.6×537	38,449.2 cal.
Total heat absorbed by water	118229.7 cal.
Efficiency of stove $= \frac{\text{Output}}{\text{Input}} = \frac{118229.7}{171,336}$	69%
Kilowatt-hours of work $\frac{112 \times 5.31}{1000} \times \frac{1}{3}$	.198 kwt. hr.
Cost of operating stove to boil egg for 3 minutes at 8¢ per kwt.hr.	1.6 cts.*

(Signed) Delphine Be Quillard.

Dec. 8, 1913.

Manipulations. The small electric stove was connected to the A.C. main and an ammeter put in series with it and a voltmeter shunted across its terminals. I found the weight of the kettle empty, and filled two-thirds full of cold water. After taking the temperature of the water, the kettle was placed on the stove and the current turned on. Readings of the voltmeter and of the ammeter were taken every minute. When the water began to boil the egg was put in and the boiling continued for three minutes.

The kettle and hot water were weighed again. From the barometer reading, the temperature of boiling water for the day was determined. The computations as indicated in the tabulation were made. The cost of boiling the egg was found to be 1.6 cents and the efficiency of the stove 69 per cent.

* Several eggs might have been cooked at a very slight increase over the above cost for one, as the dish and quantity of water were sufficiently large.—Instructor's Note.

EXPERIMENT NO. 15

THE IMMERSION HEATER

The experiment was repeated, using a smaller dish and an immersion heater. See Fig. 14.

Results:

Weight of dish	145.2 grams
Weight of dish and cold water	455.0 grams
Temperature of cold water	23.8° C.
Weight of kettle and contents after boiling egg 3 minutes (4.5 minutes)	425.0 grams
Temperature of boiling water for day	99.45° C.
Temperature change of water	75.65° C.
Fall of potential through heater	111.0 volts
Current through heater	6.06 amps.
Resistance of heater	18.31 ohms
Heat developed in $4\frac{1}{2}$ minutes = $.24\times(6.06)^2\times18.31\times4.5\times60$	43,505.1 cal.
Heat absorbed by water in coming to boiling pt.	24,533.3 cal.
Heat used in boiling away 30 gms. of water	16,110.0 cal.
Total heat absorbed	40,643.3 cal.
Efficiency of heater	93.4%
Work done by heater $\frac{111\times6.06}{1000}\times\frac{4.5}{60}$	.05 kwt. hr.
Cost of boiling egg at 8¢ per kwt. hr.	0.4 ct.

(Signed) Delphine Be Quillard.

December 8, 1913.

See Fig. 15 (Philippi's arrangement) for suitable diagram of connections containing instruments used.—Compiler's Note.

EXPERIMENT NO. 16

MAKING COCOA AND CANDY WITH THE AID OF ELECTRICITY

Contributed by F. H. Beals

Object. To find the cost of making Cocoa and Candy (Fondant) and of boiling water on the electrical disk stove; also determining the efficiency of the stove.

Apparatus. Weston Voltmeter and Ammeter, Disk Stove, Double Boiler, Thermometer, Graduate. See Fig. 18.

Performed by Helen Burnett and Marion Butler.

Making Cocoa, Experiment A.	Making Fondant Candy, Experiment B.	Boiling Water, Experiment C.
Case I Ingredients Cocoa, 8 level teaspoonfuls. Sugar, 6 level teaspoonfuls. Cold water, 2 cups (500 c.c.). Cold milk, 2 cups (500 c.c.). Method Pour the cold milk and water into the metal boiler on the disk-stove. Make the electrical connections as shown on the sketch; record time and turn on current. Mix the cocoa and sugar well together in a bowl; add $\frac{1}{4}$ cup of cold water and stir to make a thin paste. Pour some of the hot mixture into the bowl and wash out all the cocoa into the boiler. Bring to a boil and boil three min. Case II Ingredients Cocoa, 3 level tablespoons. Sugar, 3 level tablespoons. Water, 2 cups (500 c.c). Milk, 2 cups, (500 c.c.) Method Mix cocoa, sugar, and water thoroughly. Bring milk to boiling point; add first mixture and bring all to scalding point. (About 80° C.)	Ingredients Sugar, 1 cup (2 oz.) Water, $\frac{3}{8}$ cup, (96 c.c.) Cream of tartar, $\frac{1}{16}$ teaspoonful. Method Mix sugar, cream of tartar, and water together in lower part of double boiler. Place on the disc-stove, having had the current on 2 min. to allow for heating. Record time. Stir mixture until sugar is completely dissolved, boil uncovered until a drop of the mixture dropped from the end of a spoon spins a thread, or until it forms a thick, jelly-like consistency when dropped into cold water. Turn off current, first recording time. Pour the mixture upon a well-greased marble slab or a flat platter. When sufficiently cool so that the mixture does not adhere to the finger when touched in the center, beat with wooden spoon until the mixture becomes too hard to beat, then knead with the hands. When it becomes sufficiently cooled, roll into small balls for bonbons.	Case I 1000 c.c. of water in the lower part of the double boiler, and upon the disk-stove. Bring to boiling point, recording time taken to perform experiment. Case II Place 250 c.c. of water in the lower part of the double boiler, and 500 c.c. of water in the upper part. Place both parts on the disk-stove, together and heat. Record time taken to heat water in upper boiler and obtain other necessary data.

	Outer Parts of Double Boiler.				Both Parts of B. B.
	Cocoa, Experiment A.		Candy, Experiment B.	Water, Experiment C.	
Time required to heat plate	2 min. Case I	2 min. Case II	2 min.	2 min. Case I	2 min. Case II
Volts (average)	114.5	119.0	115	117	117
Amperes (average)	3.6	3.8	3.7	3.7	3.7
Watts-volts amperes	412.2	452.2	425.5	432.9	432.9
Weight of boiler	630 g.	630 g.	630 g.	630 g.	630 g.
Water equivalent of boiler (approx.)	0.1	0.1	0.1	0.1	0.1
Water equivalent of boiler (approx.)	63.0 g.	63.0 g.	63.0 g.	63.0 g.	63.0 g.
Quantity of water used	(2c.)500 c.c.	(2c.)500 c.c.	96 c.c.	1000 c.c.	750 c.c.
Quantity of milk used	(2c.)500 c.c.	(2c.)500 c.c.			
Tem. of water alone after 8 min.	....	100° C.			
Tem. (cocoa and water) when finished	92° C.	79° C.	......	96° C.	95° C.
Tem. water before heating	26° C.	25° C.	21° C.	25° C.	25° C.
Tem. milk before heating	15.5° C.	15° C.			
Total time taken to make	24 min.	14.5 min.	15.5 min	15 min.	32 min.
Cost to make 1000 c.c. of cocoa	$.016	$.0109			
Cost to make 235 g. of candy	....	....	$.0116		
Cost to boil 1000 c.c. of water in lower boiler	....	....	......	$.0108	
Cost to heat 250 c.c. of water in the lower boiler, and 500 c.c. of water in the upper boiler, i.e., cost of both	....	....	......	......	$0.023
Practical efficiency (water)	....	72%	......	76%	26%
Theoretical efficiency (water and dish)	....	81%	......	81%	29%

Conclusion. It is evident that the electric disk stove is not nearly as efficient when both parts of the doubler boiler are used as when the single dish is used. And also that the real efficiency calculated for actual heating of water is less than efficiency reckoned on the basis of amount of *metal* and *water* used.

$$\text{Practical efficiency} = \frac{\text{Weight of water} \times \text{change in temp.}}{\text{No. watts} \times \text{No. seconds} \times .24}$$

$$\text{Theoretical efficiency} = \frac{(\text{weight of water} + .1 \text{ wt. of boiler})\text{change in tem.}}{\text{No. watts} \times \text{No. seconds} \times .24}$$

In calculating efficiency we considered two cases.

(1) Practical efficiency, when we took into consideration only the heating of the water actually used and (2) theoretical efficiency, when we considered the heat absorbed by both the water and the dish.

The cost of making 2 quarts of cocoa was about 2.7 cents; for making over ½ pound of candy, 1.16 cents.

INSTRUCTOR'S NOTE. The second year of science for girls at Barringer High School differs from the course for boys, one-fifth of the girls' year being devoted to cooking. The work in electricity for girls is correlated with this branch of domestic science. All the electrical experiments, except Case II above, were performed in the physical laboratory; the second method of making cocoa seemed to the Cooking Department more satisfactory.

There can be no doubt that the exercises in electrical heating and cooking have touched the daily life and experience of the girls who have done them. They are incomparably superior to the old, conventional experiments of the physical laboratory, so far as the girls are concerned.

It may be of interest to observe that the above method of measuring efficiency by the amount of water evaporated has been used at the Barringer High School to obtain the efficiencies of an electric toaster and an electric stove, and conversely to obtain the latent heat of vaporization.

The highest efficiencies were obtained when there was contact, as in the case of the electric flat iron, and the lowest when the heating was chiefly by radiation, as in the electric toaster.

Domestic electrical contrivances are not of course primarily designed to serve as a means of affording physical quantities which may be readily determined with scientific exactness; but rather to permit useful work to be performed with expedition, convenience and minimum cost.

Hence individual results obtained from different sources may disagree, without, however, detracting from their educational value.

Lack of space compelled us to defer the publication of several additional exercises on domestic electrical apparatus. Upon request we will mail copies of the following:

Cost of Frying on the Disk and Oblong Stoves.

Cost of Operating an Electric Toaster.—COMPILER'S NOTE.

AN ELECTROLYTIC CURRENT RECTIFIER

(Prepared by the Compiler)

In the following pages we devote considerable space to a description of an apparatus known as a Nodon Valve or Electrolytic Current Rectifier.

We were extremely surprised at being unable to find a single High School text-book which gave even a cursory reference to this subject; and although we do not manufacture apparatus of this type, we are publishing the results of our experiments.

We do so because there are many schools which are limited to alternating current line service, the character of which necessarily is not adapted to the performance of many experiments requiring direct current, which should form part of a High School course.

In addition apart from its practical value as a means of transforming alternating current into pulsating direct current, the apparatus merits the careful consideration of all science teachers because it may be easily and cheaply constructed; and forms the basis of an experiment that should be included in every laboratory schedule.

That there is a pressing demand for some such device is testified to by the numerous inquiries we have received for information pertaining to a simple form of rectifier; and it is a great pleasure to present the results of our investigations.

While our work is not exhaustive, it furnishes ample material for exercises, and when practicable we should be glad to receive reports from instructors who decide to include the rectifier as part of their laboratory equipment.

Students are certain to become interested in a method of converting "a.c." into "d.c.," and especially will this be the case when it is explained how often some type of converter is used in practical work, when it becomes necessary for instance, to charge an automobile storage battery at once, and no "d.c." is available.

The Nodon valve form of rectifier has been selected for description, because it is extremely simple in construction, and a "valve" can be made in a few minutes at a trifling cost.

It cannot be ranked as an efficient form of rectifier, and no such claim is made for it; but fortunately great efficiency in transformation is not a matter of vital importance in school laboratories, the main desideratum being to obtain direct current service when required.

Although also somewhat erratic in its behavior, in that the pulsating direct current it furnishes is not always steady, it would be difficult to find a single piece of apparatus which is more interesting and instructive than a Nodon Valve, when used in connection with accurate measuring instruments.

The Nodon Valve

Small Nodon Valves are inexpensive and are very easily made. All that is required is a jar containing a plate or rod of aluminum partly immersed in a saturated solution of bicarbonate of soda, and an inactive conductor.

Sheet aluminum $\frac{1}{16}$ inch thick costs less than $1.00 per square foot at retail. If it is too tough or brittle to bend easily, aluminum can be softened by holding over a Bunsen flame. In order to obtain good results it is of great importance that the aluminum employed is practically pure. Much of the commercial aluminum used in manufacturing condensers, etc., is adulterated with zinc.

We found that such material gave low efficiency, in some cases even causing the pointer of the direct-current instrument to vibrate to an extent likely to damage the movement.

For experimental purposes, several of these valves were constructed at the Weston laboratories. They consisted of glass jars 6 inches in diameter and 7 inches in height, containing plates of aluminum and lead. The lead plates were 10 by $2\frac{1}{2}$ inches in area, and $\frac{1}{16}$ inch in thickness. The aluminum plates were 1 inch by 10 inches, also of $\frac{1}{16}$ inch thickness.

It was found that the dimensions of the electrodes, jars, etc., were of no special consequence, and that equally good results were obtained when lead, iron or carbon were used for the inactive pole.

EXPERIMENT NO. 17

TESTING A NODON VALVE WITH DRY CELLS

When the aluminum pole of one of these valves was connected with the carbon pole of a battery of two dry cells, and a voltmeter was included in the circuit, the latter indicated 1+ volts. See Fig. 19 (e.m.f. of cells was app. 2.8 volts). The pointer rapidly dropped to nearly zero, finally becoming stationary at 0.11 volt. When the test was repeated with a milliammeter, the initial current was 0.40 ampere, which finally dropped to 0.0015 ampere, where it remained.

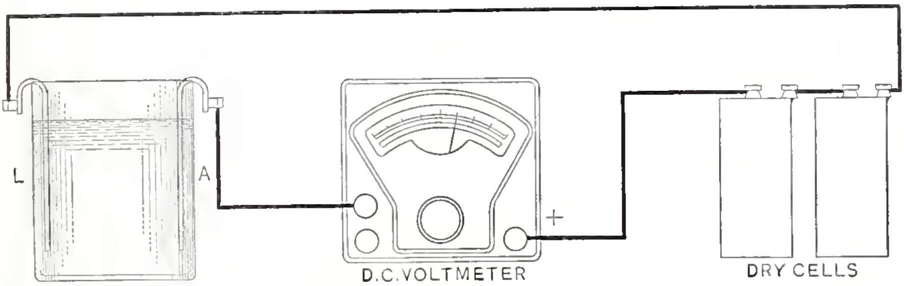

FIG. 19.—TESTING A NODON VALVE WITH DRY CELLS.

The initial current is of course affected by resistance of instrument and leads, the dimensions of the valve, etc.

The Action of a Nodon Valve

The reason why a Nodon valve permits a flow of current practically in only one direction is substantially as follows:

When a direct current is passed through a solution made of bicarbonate of soda, ammonium phosphate or any similar alkali, by means of two pieces of immersed iron, lead or carbon, it will be found that gas bubbles form on the plates, and will rise freely to the surface. If alternating current be used instead, almost no gas is formed. In either case the liquid acts as a resistor, which can be shown by connecting an ammeter in series and changing the distance between the plates. The temperature of the solution is raised by the passage of the current.

When, as stated in Experiment No. 17, a strip of aluminum takes the place of one of these lead or carbon plates, it will be

found that the current will still flow freely when the circuit is completed with the (+) plus pole of the battery connected with the lead or carbon.

But, if the + pole is connected with the aluminum, the initial current rapidly diminishes. This is partly due to the fact that gas bubbles form on the aluminum plate, and rise to the surface of the liquid as they are crowded off by others. These gases are oxygen and hydrogen. In this respect, the action of the valve resembles that of an ordinary simple cell consisting for instance, of plates of zinc and copper, dipped in an acid solution. But there is another and more complex action taking place. Substantially, the aluminum is attacked by these gases, which combine with it to some extent, and form upon its surface a non-conducting layer of hydroxide of aluminum. If the aluminum plate could be completely covered with this hydroxide, it would practically become a non-conductor, and almost all electrical transmission would cease.

The fact is, however, that when a direct current is used as stated, some current continues to flow from the aluminum to the lead, "seeping" through the hydroxide layer (so to speak).

When alternating current is used instead (with a single valve) the latter may be said to open and close successively for each cycle so that one-half of each alternating current wave is checked, the other half passing through and having a pulsating direct effect. The valve, however, is not perfect in its action, and may be said to "leak."

EXPERIMENT NO. 18

TESTING A NODON VALVE WITH A DIRECT CURRENT SERVICE LINE

When one of these valves was connected with a source of direct current (110 volts) in series with a lamp bank and an ammeter, the following results were obtained at the instant the circuit was closed. Plus (+) to lead pole, 1.95 amperes. Plus (+) to aluminum pole, 1.10 amperes.

When the circuit had remained closed for thirty seconds with + to aluminum, the current was reduced to 0.15 ampere, and at the end of two minutes the total current flowing as indicated by a direct current milliammeter was 0.020 ampere.

EXPERIMENT NO. 19

TESTING A NODON VALVE WITH ALTERNATING CURRENT

When alternating current is used in connection with a Nodon Valve, it is assumed as already explained, that pulsating direct current is obtained, since current is not supposed to flow from the aluminum to the lead.

While this is not strictly the case, there is enough interference to produce a current which is sufficiently direct to be measurable by means of a direct current movable coil permanent magnet ammeter or voltmeter.

But such an instrument will respond only to the direct current pulsations, and since a Nodon Valve will by no means rectify

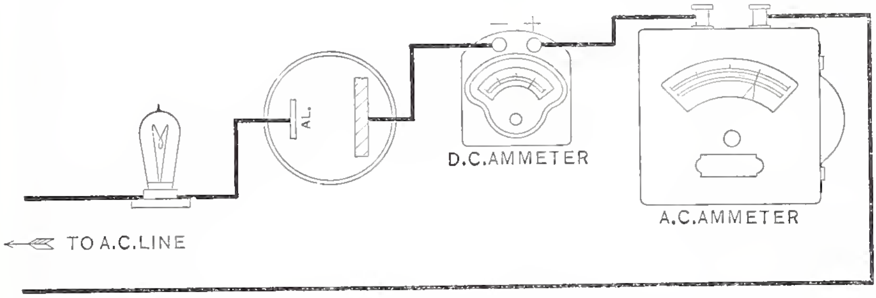

Fig. 20.—Testing a Nodon Valve with Alternating Current.

Instruments required are a Model 280 Weston Ammeter, range 5 amperes, and a Weston Model 155 A.C. Ammeter, range 5 amperes.

the current entirely, the results obtained when the so-called direct current is tested with accurate instruments will seem perplexing and apparently paradoxical.

For instance, when both an alternating and a direct current ammeter were connected in series with a Nodon Valve, a lamp bank and a source of 110-volt alternating current (see Fig. 20), the following results were obtained:

A. C. Line, 110 Volts.	Time in Minutes.						
	0	1	2	3	4	5	10
D. C. Instr....	0.05	0.50	0.61	0.65	0.67	0.67	0.69 ampere
A. C. Instr.....	1.80	1.30	1.25	1.23	1.23	1.24	1.25 amperes

EXPERIMENT NO. 20

EFFICIENCY TEST OF A NODON VALVE

In order to further investigate this matter, instruments were added to the circuit until the general arrangement was as shown on Fig. 21. The apparatus consisted of a Weston Standard Wattmeter connected with the A.C. line, directly indicating the power consumed. The instruments used for measuring the direct current were one Model 280 Voltmeter and one Model

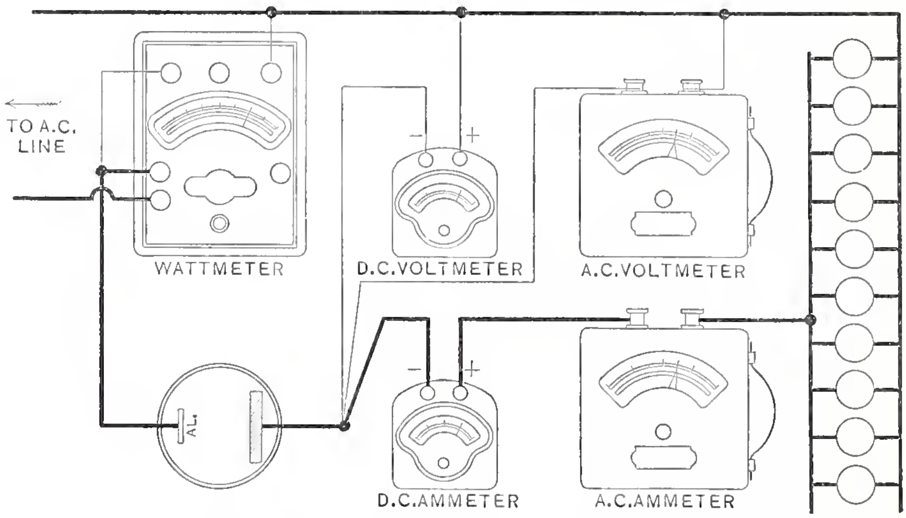

FIG. 21.—EFFICIENCY TEST OF A NODON VALVE.

280 Ammeter, which indicate with direct current only; one Model 155 Voltmeter and one Model 155 Ammeter. The Model 155 instruments are of the "soft-iron" type and are operative with either direct or alternating current. Following are the results obtained:

WATTS ON A. C. LINE 150.0

Line Voltage, 110 A. C.	Volts.	Amp.	Watts.
Direct current instruments.	36.5	0.9	32.8+
Alternating current instruments.	64.0	1.65	105.6

EXPERIMENT NO. 21

EFFICIENCY TEST WITH TWO NODON VALVES IN SERIES

Two valves were then employed in series (lead to aluminum) but there was no important difference in efficiency, as shown by the following data:

WATTS ON A.C. LINE 138

	Volts.	Amp.	Watts.
Direct current instruments............	27.5	0.94	28.85
Alternating current instruments.........	46.5	1.55	72.07

EXPERIMENT NO. 22

PUNCTURING THE INSULATING WALL OF A NODON VALVE

We have already found by Experiment No. 20 that a direct current and an alternating current ammeter connected in series with each other and operated through a Nodon valve will not give corresponding indications. The reason for this is fully explained in due course.

But meanwhile, an interesting little experiment (original, we believe) may be easily performed, which consists in "punching a hole in the insulating wall." All that is required for this operation is an alternating current outfit as shown on Fig. 20 and a piece of stiff iron wire, one end of which is bent at right angles to form a hook about 2 inches long. The end of this hook should have a sharp point.

If the aluminum plate is touched below the surface of the liquid with this iron point, the direct-current ammeter instantly drops to nearly zero, and the total current increases, as indicated by the alternating current ammeter and the improved luminosity of the lamp. See Fig. 22.

If about eight lamps (16 c.p.) are connected in multiple for a load instead of only one, so that the current will be about

three amperes, the point of the hook will adhere to the aluminum to some extent, as if it were fused in by the action of the current.

Bubbles rise freely from the hook while in contact with the aluminum, indicating that the aluminum hydroxide will not adhere to the iron; and hence, since the point of the hook has been forced through the layer, it conducts current from the aluminum through the liquid to the lead, changing the apparatus into a simple liquid resistor.

Only one valve should be used to get the best effect in this test.

Construction and Arrangement of the Electrolytic Currrent Rectifier

It is obvious that the only effect produced by one or more Nodon valves in series, is to impede the flow of an alternating current in one direction. The resultant direct current cannot have an efficiency greater than 50 per cent of the total alternating current, and is actually only about 25 per cent or less. It is possible, however, to obtain greater efficiency by arranging four valves in the form of a parallelogram and connecting the alternating current in such a manner that both halves of the current will be utilized to produce a direct current.

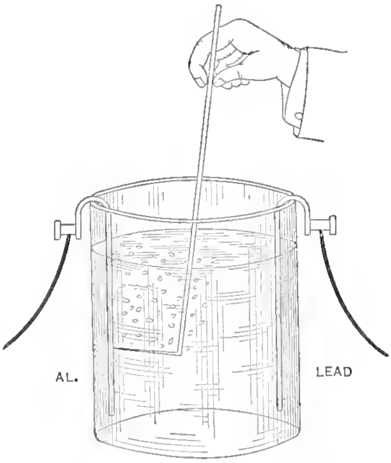

Fig. 22.—Puncturing the Insulating Wall of a Nodon Valve.

One of these rectifiers was purchased for experimental purposes and tested in the Weston laboratories. It consisted of four porcelain jars, each about $5\frac{1}{2}$ inches in diameter and 11 inches in height, provided with an insulated top and binding posts.

Each jar contained a rod of aluminum and two plates of lead, the latter being connected together. The solution used was bicarbonate of soda. The general design was such that a large percentage of the alternating current was converted into direct current.

The Theoretical Operation of the Electrolytic Current Rectifiers

The current from an A.C. source enters at *a*, See Fig. 23, is checked at *k*, but may flow through the lead plate *b* to *c* to *d*, is again checked at *i*, but may flow through the instrument (or load) to *e*, continue through *f* and *g* and out to *h*, constituting half a cycle. The other half operates through *h*, is checked at

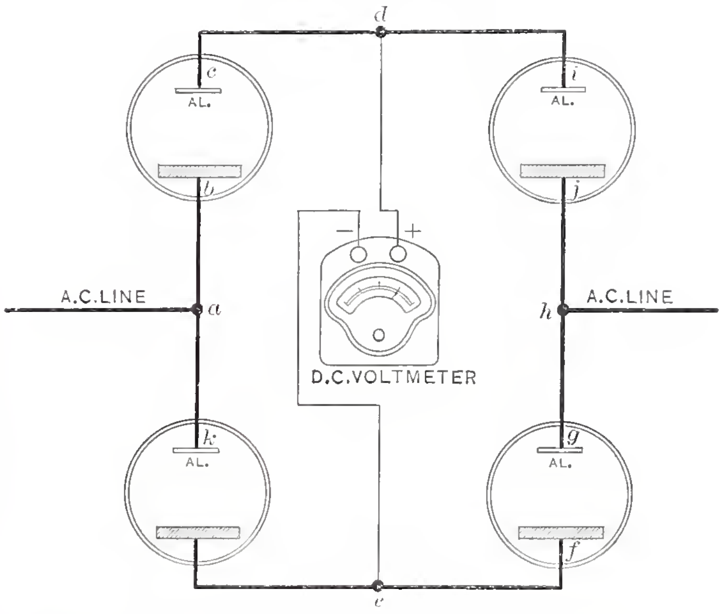

Fig. 23.—The Electrolytic Current Rectifier.

g, but follows *j* and *i* to *d*, is checked at *c* and flows through the instrument to *e*, etc.

A rather surprising feature of these rectifiers is that the direct-current voltage of the apparatus when the voltmeter is connected as shown on Fig. 23 is sometimes 20 per cent higher than the A.C. line voltage. This is only the case, however, when the direct current used is negligibly small.

EXPERIMENT NO. 23

EFFICIENCY TESTS OF A COMMERCIAL ELECTROLYTIC CURRENT RECTIFIER

In order to obtain some data in relation to efficiency, a test was made having a continuous run of two hours. See Fig. 24. Following are the results obtained:

A.C. LINE, VOLTAGE 110

Watts on A.C. Line.	Pulsating Direct Current.				Tem. of Solution.	Efficiency.
	Volts.	Amp.	Watts.	Time.		
320	85.0	1.70	144.5	0	23° C.	45.1%
380	87.0	1.72	149.6	1 hr.	32° C.	39.4%
450	85.0	1.70	144.5	2 hrs.	42° C.	32.1%

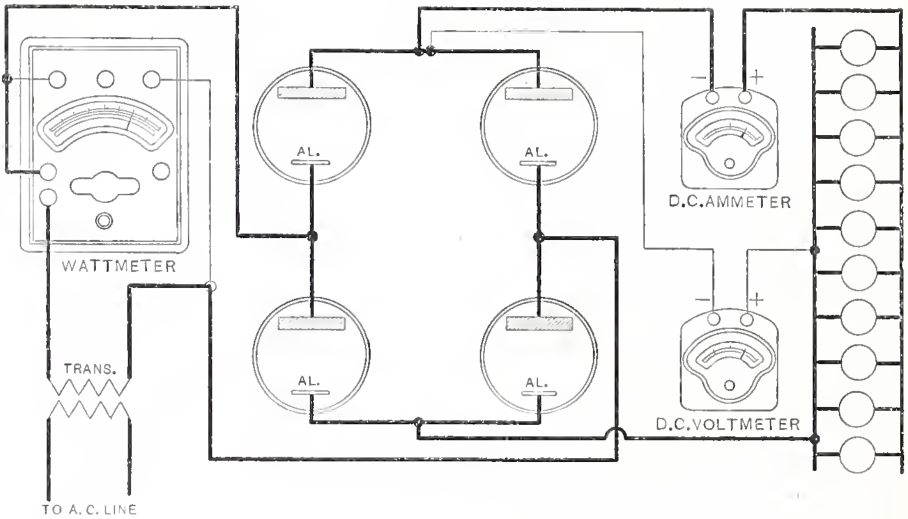

FIG. 24.—EFFICIENCY TEST OF AN ELECTROLYTIC CURRENT RECTIFIER.

When the apparatus was connected directly with the A.C. line and no direct current was drawn, 45 watts were consumed. When nothing but a high resistance voltmeter was connected with the direct-current binding posts, it indicated 133 volts.

Alternating-current voltmeters and ammeters were also used in making this test. Their indications taken simulta-

neously with the direct current observations averaged 11 per cent higher.

Some experimenters state they have obtained greater efficiency by introducing a transformer in the circuit so as to reduce the voltage to 55 or below.

Following is the result of a test made under such conditions:

A.C. VOLTAGE 55

Watts on A.C. Line.	Pulsating Direct Current.				Tem. of Solution.	Efficiency.
	Volts.	Amp.	Watts.	Hours.		
88.0	25.1	1.27	31.88	0	25.2 C.	36.2%
80.0	22.0	1.10	24.20	1	28.0 C.	30.2%
76.0	20.1	1.05	21.10	2	30.0 C.	27.7%

NOTE.—It should be distinctly understood that it is not claimed that either of the results obtained is conclusive. On the contrary, it is quite probable that increased efficiency may be obtained. It is also likely that some modifications of the apparatus including a water jacket or some other contrivance for keeping the temperature from rising unduly would have advantages.

Caution. It is safest to include a lamp bank or some other resistor in the line when the rectifier is first used or after it has been idle for even a short time. There is often a current surge of 20 or more amperes when the circuit is first closed. This is due to the fact that the hydroxide has not had time to form. This surge also causes a strong pulsating current to develop at times, and unless fuses are put in both lines, damage may be done to apparatus in circuit.

These rectifiers may be used to charge small storage batteries, but care should be taken to connect an ammeter in circuit together with a rheostat or bank of lamps, in order to regulate the current.

The top part of the jars as well as the cover to which the elements are fastened should be dipped in hot paraffin before setting up, so as to prevent the solution from creeping.

The liquid should occasionally be renewed, since it seems to deteriorate.

Instrument Indications in Connection with a Rectifier

The reason for the difference between the indications of the direct and alternating current Weston instruments when used to measure the output of an electrolytic rectifier, is explained in an article by Albert Nodon, in Vol. I, of the Transactions of the International Electrical Congress, St. Louis, 1904, entitled "Electrolytic Rectifiers—An Experimental Research," page 510.

This experimental research includes charts showing the wave form of the rectified current as obtained by means of the ondograph or oscillograph.

If this rectified current is measured by a Weston alternating current ammeter, the result is that the instrument readings represent the effective current, which will be the square root of the mean square of the instantaneous values.

Whereas, if a direct-current ammeter is used, its indications depend upon the arithmetic mean value of the instantaneous values of the pulsating current. If the transformation were perfect the difference between the indication of the two types of instruments would be 11 per cent.

The fact is, however, that the transformation is *not* perfect. The results obtained with a single valve prove this, and even when four valves are arranged in parallelogram form, there is a loss due to leakage as well as to resistance. This can be directly proven by measuring the pulsating current by means of an induction meter which will not indicate with direct current. It can be simultaneously shown that the direct-current instrument responds only to the direct-current pulsations; the alternating current instrument gives the combined affect of direct and alternating current; and the induction meter indicates only the alternating current (or leakage), its indications being approximately the difference between the other indications.

In charging storage cells and in running direct-current motors as well as in the electro-disposition of metals, the above statements should be taken into consideration, since it is obvious that the only effective current for such work obtained from rectifiers of this type will be due to the direct-current pulsations.

An article entitled "The Chemistry of the Electrolytic Current Rectifier," by Donald McNicol, will be found in the August, 1913, number of the "Electrician and Mechanic."

THE WESTON DIRECT CURRENT MOVABLE COIL SYSTEM

(Prepared by the Compiler)

This system consists primarily of a coil which can rotate freely in a strong magnetic field produced by means of a permanent magnet. When a current is flowing through it, this coil acquires magnetic properties and tends to assume a position which will reduce the distance between its poles and the oppositely magnetized poles of the permanent magnet. Springs which also serve as current conductors tend to oppose the movement of the coil.*

The Milliammeter

An instrument which consists only of a coil, a magnet, a core and an elastic metallic conductor for controlling the movement of the coil, in short a "system" as described above, is in its simplest form a milliammeter. All Weston direct-current movable-coil systems are fundamentally uncalibrated milliammeters, although they may differ in size, in the strength of their magnetic fields, in the number of turns of wire in their movable coils, and in mechanical details. This is the case because all systems of this type are operated by means of a small current; and the extent of the deflection produced depends upon the strength of this current.

The Millivoltmeter

The system as described, is also an uncalibrated potential indicator of millivoltmeter, because a definite electromotive force is needed to overcome the resistance of the movable coil and force a current through it. If, therefore, we consider the system in its simplest form as consisting only of a movable coil, a core, a magnet, and a pair of springs directly connected to a

* See also Monograph B-2.

pair of binding posts by means of leads of negligible resistance, then it follows that, *for any deflection of the movable coil at a fixed temperature the current will always be the same for that deflection.* And since the resistance of the movable coil and springs will always be the same at a fixed temperature, it also follows that under the given conditions the electro-motive force required to overcome the resistance of the movable coil, etc., and produce any desired current, will always be the same unless extra resistance is added to the circuit.

The Movable Coil Constant

The movable coil constant is the component of current and e.m.f. pertaining to a particular system, that is to say, a system of a certain type or class; and under all normal conditions such constants are fixed and unchangeable. For instance, if the current required to obtain a full scale deflection is .01 ampere, and (r) the resistance of the movement is 6 ohms, then the e.m.f., required will be $E=Ir$, in this instance being

$$6\times.01=.06 \text{ volt},$$

and the power required to produce a full-scale deflection will be

$$.01\times.06=.0006 \text{ watt}.$$

To extend the range of such an instrument for voltage measurements, it will be necessary to add a resistor to the circuit, and the resistance of such a resistor in ohms per volt is found by the formula $R=\frac{E}{I}-r.$

For instance, to obtain a 1-volt range, the added resistance in this instance will be:

$$R=\frac{1}{.01}-6=94 \text{ ohms}.$$

Necessarily, to make a 100-volt instrument of the movement, a total resistance of 10,000 ohms will be required, and all other ranges will have a directly proportionate resistance.

The Ammeter *

In attempting to use the movement already referred to for current measurements, it will be apparent immediately that no current greater than .010 ampere should be passed through it. If therefore a larger current than this is to measured, some contrivance must be attached which will permit a larger current to flow, and yet limit the quantity flowing through the movement. This is most easily accomplished by means of a divided or shunted circuit.

For instance, if a resistor is constructed of insulated wire having the same resistance as the movement, and is connected directly with the binding posts of the instrument, and the binding posts are then connected with a source of current, it may be deduced that such a current will split; and since the resistor has the same resistance as the movable coil, the current will split evenly, half of it going through the movement and half through the resistor. But, the movement will only respond to the current flowing through it, and not to the current flowing through the resistor. Since these currents are alike, it follows that the pointer will indicate half of the total current flowing. In other words, the ampere range of the instrument has been doubled.

To determine how to still further extend the ampere range of the instrument it is only necessary to refer to the laws relating to divided circuits. The current flowing through two parts of a divided circuit will be directly proportional to the resistances of these circuits. If, for instance, the shunt coil measured .06 ohm and the movement 6 ohms, then the current would be as .06 is to 6, that is, the current through the shunt would be 100 times as great as that passing through the movement. For it must not be forgotten that the voltage at the binding posts is the same for the movement as it is for the shunt coil, and that

* For data relating to Weston movable systems, see also "Elements of Electricity," Timbie, Chap. XIV.; "Physics," Mann and Twiss, page 169; "Practical Physics," Black and Davis, page 284; "Laboratory Manual," Black and Davis, page 64; "High School Physics," Carhart and Chute, page 371; "A High School Course in Physics," Gorton, page 405; "Electrical Instruments and Testing," Schneider and Hargrave, Chap. 4, and "Lessons in Practical Electricity," Swoope, Lesson 18.

consequently the less the resistance of the shunt the greater will be the current flowing through it. A point could therefore be reached where the shunt would have so low a resistance that it would carry practically all of the current, and not enough would flow through the movement to make it operative. Such a shunt would be described in practice as not having enough "drop," meaning that the potential difference between its extremes would be insufficient for the purpose for which it was intended.

In practical work the shunts are usually constructed to have a standard drop of 50 or 100 millivolts. The resistance of the system is increased by adding non-inductive zero temperature coefficient material in series, so as to increase the e.m.f. required to produce a full scale deflection to 50 or 100 millivolts or some other value, according to the type of instrument, and the drop of the shunt.

THE WESTON ALTERNATING AND DIRECT-CURRENT "SOFT IRON" SYSTEM

(Prepared by the Compiler.)

The direct-current movable-coil system described in the preceding article is inoperative with alternating current, because its field as produced by a permanent magnet has fixed polarity. Consequently when an alternating current is passed through the movement, the polarity of the movable coil is thereby continually reversed, and the movement oscillates instead of being deflected. The effect of an alternating current when applied to a direct-current movement can be plainly seen by the vibration of the pointer,* but of course there is no continuous motion in one direction by means of which an alternating current could be measured.

The movable element of the Weston soft-iron system consists of a small curved piece of iron fastened to a light pivoted shaft. This shaft is also provided with a truss form of pointer made of thin aluminum tubing, to which is attached a balance cross and a small vane. The shaft moves in jeweled bearings.

* Experiments of this kind if protracted, neither improve the sharpness of the pivots nor lengthen the life of the pointer of a d.c. instrument.

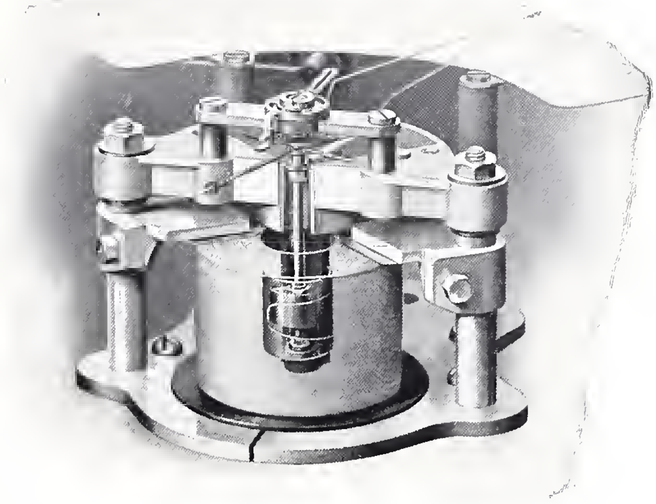

FIG. 25.—PHANTOM VIEW OF WESTON MODELS 151, 155, 156, 159, 160.
Moving Parts of "Soft Iron" Voltmeters.

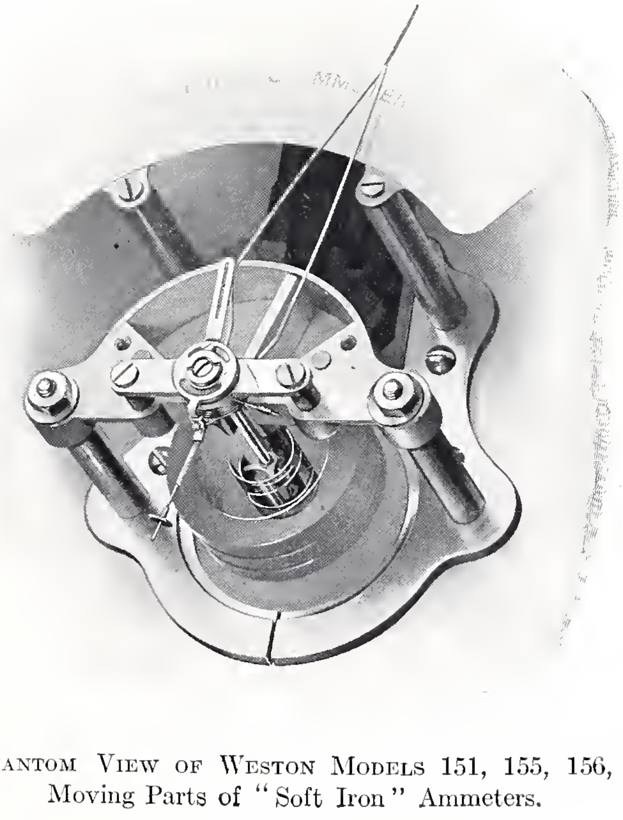

FIG. 26.—PHANTOM VIEW OF WESTON MODELS 151, 155, 156, 159, 160.
Moving Parts of "Soft Iron" Ammeters.

Near this movable element and concentric with it is a small curved tongue of soft iron which is rigidly held by a suitable support. (See Figs. 25 and 26.)

Surrounding these is a field coil, made up either of a large number of turns of insulated wire when the instrument is to be used for the measurement e.m.f. or else of one or more turns of heavy conducting material, when designed for the measurement of current.

Principle of Operation. When a direct current is passed through the field, the movable element and the fixed tongue of iron become magnetized by induction; but since they are *within* the field coil, their juxtaposed ends will have like polarities. Consequently these poles will repel each other. The only resultant motion possible is the rotation of the movable element.

When alternating current is used, the polarity of the field coil will be alternately North and South, the number of reversals depending upon the frequency.

The polarities of the movable and fixed iron parts of the system will also reverse correspondingly, but although the juxtaposed parts will have constantly reversing polarities, they will have like polarities in relation to each other, and therefore will necessarily repel each other continuously, thereby imparting a rapid series of impulses to the movable element, causing a deflection in one direction only.

This deflection is opposed and therefore controlled by the action of a delicate spiral spring; hence the extent of the rotation depends upon the strength of the current flowing through the solenoid.

The peculiar shapes as well as the relative positions of the iron parts are patented features which are the outcome of much theoretical work and numerous experiments. As a result, the instrument is almost entirely free from hysteresis or lag; that is to say, the magnetization, demagnetization, and remagnetization of the iron, will be practically perfect.

If the instrument is designed for current measurements, it is so arranged that all of the current passes through the solenoid or field coil. This is also the case when intended for the measurement of e.m.f., but an adjusted resistor lies in series with the solenoid. The resistance of the instrument is thereby

increased, and the quantity of current which may flow is regulated. Precisely as in direct current movable coil instruments, the amount of current which will flow, depends upon the e.m.f. of the circuit across which the instrument is connected.

The vane or damper moves in a fan-shaped pocket which is shown in Fig. 26 with the cover removed. When this vane is enclosed it damps the movement of the system without mechanical friction. That is to say, the vane does not touch any part of the receptacle but moves through confined air.

The scales of these instruments are open and fairly uniform throughout four-fifths of the total range of deflection.

CO-OPERATORS

We extend our hearty thanks to all physics instructors who have assisted in the preparation of this monograph, either by their encouraging approval of our previous efforts, or by their suggestions and direct contributions.

Among many others, we are especially indebted to the science teachers whose names we append, with occasional extracts from their communications:

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"I would be glad if you can spare me two extra copies of monograph B-2 for class use."

Andrews, A. P., Instructor, Department of Physics, Minneapolis, Minn.

"There can be no possible question as to the service you are rendering schools. Personally, I expect to profit by it."

Baer, C. E., Department of Science, The Lincoln High School, Seattle, Washington.

"Please send *all* Monographs or other literature descriptive of such of your instruments as may *practically* be used in our modern high schools.

I am on a committee of Seattle Physics teachers, appointed to outline a revised course in electricity from beginning to end, and need your co-operation."

Barber, Fred D., Illinois State Normal University, Normal, Ill.

Barrett, J. T., Department of Physics, Lawrenceville School, Lawrenceville, N. J.

"Personally I was glad to see you entering a field where *Tin Students' Instruments* had been the only low-priced supplies available."

Beals, Frederick H., Department of Physics, Barringer High School, Newark, N. J. Formerly Prof. of Physics, Occidental College, Los Angeles, Cal.

"I hope you will continue the good work of issuing monographs containing experiments of practical value, experiments from the commercial testing laboratories and from workshops, exercises more nearly touching daily experience and commercial life than have hitherto been customary in school; real problems of the work-a-day, experiments which have living reality in the school laboratory."

Black, Prof. N. Henry, A.M. Science Master, Roxbury Latin School, Boston, Mass.

"I have yours of the 20th inst., and am much interested in your efforts to give the schools a really good electrical measuring instrument, and at the same time to suggest how they may be used to get nearer to the real practical electrical problems. You may be interested to know that last year when I was getting out the Laboratory Manual to go with the text-book, your voltmeter and ammeter was the only form of electrical direct-reading instrument, which I felt enough confidence in to illustrate. (See Fig. 38 of Lab. Man.). Go ahead with this good work."

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Burns, Elmer E., Instructor in Physics, Joseph Medill High School, Chicago, Ill.

"I have read the monograph carefully and do not see any way how it could be improved."

Cady, W. G., Professor in Physics, Wesleyan University, Middletown, Conn.

"The idea of issuing these monographs is a good one."

Clark, M. G., Superintendent of Public Schools, Sioux City, Iowa.

"I am just in receipt of 'Elementary Electrical Testing,' and wish to take this opportunity to congratulate you upon the work which you have done in bringing practical problems of industrial life directly to the school. If industrial plants in general would take this same attitude, it would present to the schools a challenge which they could not ignore.

"To what extent and in what way could I secure more copies of this monograph?"

Colton, Geo., Professor of Physics, Hiram College, Hiram, Ohio.

"I appreciate the monographs which your company is sending out and can make use of some things in them in the laboratory work of my students."

Dowd, Mr. J. E., Classical High School, Worcester, Mass.

"I will state that your monograph proved of great service and value to me, as much of the electrical apparatus we have is of your make, and the topics dwelt upon offered much information about them."

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"I plan to equip my laboratory at once with whatever is needed to carry out all that is outlined in your Monographs in Elementary Testing."

Eastman, Earl, Science Department, High School, Atlantic City, N. J.

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"Your monographs have proven a help to me. I have adopted several of the experiments you describe in my laboratory course."

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Evans, Wm. F., Girls' High School, Brooklyn, N. Y.

Fee, Lewis H., Head of Science Department, Everett High School, Everett, Wash.

Fischer, H. F., Professor University of California, Berkeley, Cal.

Foerste, August F., Instructor in Physics, Steele High School, Dayton, Ohio.

Flanders, M. M., Bliss Electrical School, Takoma Park, Washington, D. C.

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Gardiner, F., Headmaster of the Yeates School, Lancaster, Pa.

"I should like to see experiments in efficiency tests, on the small transformer, electric cooking utensils and current capacity test on commercial fuses."

Glenn, Earl R., Department of Physics, Froebel School, Gary, Ind.

"I have read the literature you sent with great interest and profit. Science instructors owe much to the company you represent."

Gorton, F. R., Professor of Physics, Michigan State Normal College, Ypsilanti, Mich.

"Your communication regarding the publication of B-4 compilation of laboratory exercises is at hand. I think the subject matter excellent, but feel that the experimental part is too full in some points and deficient in others. I shall be glad to see the publication."

Graham, Prof. W. P., College of Applied Science, Syracuse University, Syracuse, N. Y.

Griffin, Chas. E., Head of Science Department, San Bernardino High School, San Bernardino, Cal.

"I think at the present time the greatest need in the teaching of electricity in our high schools is an apparatus for the demonstration of alternating current phenomena. Your plan of co-operation appeals to me as being especially desirable."

HAMMOND, H. E., Physics Department, Kalamazoo Public Schools, Kalamazoo, Mich.

"I believe your company is doing a good work in putting out these monographs, and I think that there ought to be a response in a business way, or Weston instruments do what they are intended to do."

HATHAWAY, F. R., Physics Director, Classical High School, Salem, Mass.

"I received the two monographs and hope to take advantage of the suggestions contained therein, in teaching electricity this coming winter."

HEDRICK, WM. A., Instructor in Physics, McKinley Manual Training School, Washington, D. C.

"I like the monographs very much and their aid has persuaded one of the teachers to try the drop of potential along a wire, that I was not able to do before. We will take great pleasure in calling the attention of the physics Teachers' Ass'n to your instructive monographs."

HULL, PROF. G. F., Wilder Laboratory, Dartmouth College, Hanover, N. H.

"You are doing a great service to scientific teachers in sending out this literature."

INGVALSON, EDWARD, Instructor in Physics, Lanesboro Public Schools, Lanesboro, Minn.

"There is certainly need of reform as far as Lab. measuring apparatus is concerned, and I believe you are doing much good in circulating such literature as your monographs. *The toy apparatus we have is a farce.* Most science teachers know this but are handicapped in improving conditions."

KELBER, C. M., Department of Physics and Chemistry, Petersburgh High School, Petersburgh, Ill.

"Perhaps some science teachers would find it suggestive if you were to describe a method for making efficiency tests of commercial electric heating units such as disk stove, percolator, etc. I have found such exercises very conducive to interest in my class work."

KILLEN, A. H., Instructor in Physics, Flushing High School, Flushing, N. Y.

LYON, LESLIE W., Department of Physical Science, Burlington High School, Burlington, Iowa.

"I would particularly like to have discussed the measurement of electric power in such experiments as determining the efficiency of electric lights, electric iron, heating plates, etc."

Marble, Milton M., Department of Physics, New Haven High School, New Haven, Conn.

"Please send with instruments, 25 copies of Monograph B-2 for students' use, and oblige."

Marvell, Sumner E., New Bedford High School, New Bedford, Mass.

"I found your monographs helpful in the physics work of the school. I have always felt that a closer contact between our teaching and commercial apparatus would be of great assistance to us."

McKenzie, Monroe R., Professor of Physics, Parsons College, Fairfield, Iowa.

Moore, Prof. J. C., Master in Science, Worcester Academy, Worcester, Mass.

"I wish to say that the monographs, especially B-2 and B-3, are exceptionally useful to science teachers. We hope that you will continue to issue them and suggest practical work in electrical measurement. You will doubtless be interested to know that they have stimulated us to equip a laboratory for electrical work, separate from our regular physics laboratory."

Moore, J. Colin, Instructor in Electricity, Lake High Manual Training School, Chicago, Ill.

"I shall be glad to make some suggestions for experiments which may be of use to others."

Nye, Arthur W., Department of Electrical Engineering University of Southern California, Los Angeles, Cal.

"I received the monographs early in the summer and was favorably impressed with them. I hope that you will continue their publication and that you will also publish some dealing with high-grade electrical instruments. There seems to be a lack of printed material about really *high grade* practical engineering electrical measurements."

Pace, Miss Lillian, Central High School, Washington, D. C.

"I have always thought that something of the sort sent out by makers of instruments which we use would be most acceptable and am glad you have entered in this work. It will give me pleasure to co-operate with you and make suggestions."

Peet, J. C., Department of Electricity and Chemistry, Technical High School, Harrisburg, Pa.

"Your experiment on the Heating Effect of current is especially good. I should like to see you add one on Chemical Effect, using the copper volt-

meter to standardize an ammeter. Keep up the good work started in these monographs."

Philippi, H. C., Department of Physics, State Normal School, Bellingham, Wash.

"I should be glad to have you discuss in future monographs any practical electrical measurements suitable for high-school work or for the first two years of college physics."

Pond, Ethel C., Physics Teacher, Sycamore High School, Sycamore, Ill.

"I consider publications such as yours the most valuable help a physics teacher can receive, and I wish to express my appreciation."

Poore, Chas. D., The Northern Normal and Industrial School, Aberdeen, South Dakota.

"I remember on getting your monographs, of at once being struck with the need of just such things in perfecting my electrical course."

Randall, J. A., Pratt Institute, Brooklyn, N. Y.

Ratcliff, R. F., Department of Physics and Chemistry, Central Normal School, Danville, Ind.

"Monograph B-2 is very valuable to us, especially, in that it gives sample experiments from the practical electrician's point of view. This is a phase of the work we wish to develop."

Reed, Harold B., East High School, Cleveland, Ohio.

"Have read the monographs with the greatest interest. They are a real contribution. Shall try out several of these experiments this year. Shall be glad to do anything possible to help along a good cause."

Rial, David, Instructor in Physics, State Normal School, Mansfield, Pa.

Rood, James T., Professor of Physics and Engineering, Lafayette College, Easton, Pa.

"Your idea that these monographs shall have so much intrinsic merit that they will be carefully kept in file as matter of value, is, I think, most admirable. Prosit!"

Rothermel, John J., Physics Laboratory, Eastern High School, Washington, D. C.

"I hope to be able to take some work on efficiency tests of small transformers, and probably also in electric cooking utensils. I should be very glad to have about half a dozen copies of Monograph B-2 and B-3 that I could use with one of my classes in their electrical experiments this year."

Smith, Ernest Reveley, Instructor in Physics, Syracuse High School, Syracuse, N. Y.

Turner, Geo. M., Masten Park High School, Buffalo, N. Y.

"Our work with the triple-range voltmeters and double-range ammeters Model 280 proved very satisfactory. No instrument was abused by any pupil either by accident or intent. It is our purpose to extend their use during the course in electrical work of the present school year.

Twining, H. L., Head of Physics and Electrical Engineering, Los Angeles High School, Los Angeles, Cal.

"You are making a move in the right direction in developing instruments of accuracy for high schools. I am writing a text on elementary electricity covering the first year's work and also a manual to accompany it. In it I am going to feature your instruments and recommend their use. I do this because they are the best that the world has to offer."

Twiss, G. R., Professor of Physics, Ohio State University, Columbus, Ohio.

"Replying to your letter of January 21st, which has been overlooked because of the pressure of semester examinations, I would say that I am very much interested in your enterprise looking to the publication of monographs on experiments that can be made with standard commercial instruments, and that have direct commercial and industrial bearings. I think that if wide publicity is given to such experiments, the movement cannot fail to be productive of much good to the pupils of the high schools. I should be glad to receive all the pamphlets of this character that you have issued up to date, and to be placed on your mailing list for other material of similar interest that you may issue from time to time."

Vawter, C. E., Professor of Physics, Virginia Polytechnic Institute, Blacksburgh, Va.

"I have four of your minature instruments and I consider them the greatest find that I have made for my electrical work in a long time. I shall get more."

Wauchope, Prof. J. A., Department of Physics, Mechanics Arts High School, St. Paul, Minn.

"I sincerely hope you will continue the publication of the monographs, as the suggestions are helpful to me and I am sure must be to many other teachers. This is excellent work that you are doing."

Webster, Evans, Head of Physics Department, English High School, City of Lynn, Mass.

"What we need most in our elementary laboratories is a galvanometer in portable form for use with the slide wire bridge, and which can be used

without a shunt box, costing not over six or seven dollars. The galvanometers usually found (made by . . .) are the most exasperating pieces of apparatus to put in the hands of students that I know of."

WOOD, LYNN H., Professor Department of Physical Science, Union College, College Point View, Neb.

"We have received your monographs B-1, B-2 and B-3. We appreciate them very much. For a long time the work in electricity in our science department has been altogether too theoretical, and we welcome any changes that will tend to make the work more practical. We are adopting many of the experiments which you give in these monographs."

WYLIE, R. M., Professor of Physics, Marshall College, Huntington, W. Va.

"Most high schools buy their equipment as you know, to fit their particular course. If the laboratory manuals which are put out by the book companies to accompany such texts as Milliken & Gale, Carhart & Chute, Gorton, or Hoadley's new book, only contained cuts of your minature instruments and precise directions for their use in the experiments in electricity, you would find many schools trying yours and using them."

AN APPEAL

If our monographs are of service to the reader, if we have succeeded in bringing him in touch with the earnest efforts of others, then, from a utilitarian standpoint, it would seem that the most suitable return any physics instructor can make, will be to reciprocate with new material or helpful suggestions, through the medium of our publications.